New Scientist

WEEKLY 9 September 2023

HOW ANCIENT HUMANS NEARLY WENT EXTINCT

THE ULTIMATE WAY TO HYDRATE

HAVE WE FOUND INTERSTELLAR ROCKS IN THE OCEAN?

SPECIAL ISSUE

THE AMAZING THEORY OF (ALMOST) EVERYTHING

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NS Live

A vaccine against fake news

Disinformation can infect our minds like a virus. How can we protect ourselves? Join psychologist Sander van der Linden at New Scientist Live on 8 October, where he will reveal how inoculation theory can create psychological "vaccines" that help people resist disinformation. His award-winning interventions expose people to weakened versions of the tricks used by social media manipulators.

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Podcast

Weekly

It is a question as old as fermentation: are "beer goggles" real? The podcast team find out. Also hear about a 3000-year-old Egyptian perfume and the people who will benefit most from brain-computer interfaces. Plus, spiders that plunder like pirates and a possible population bottleneck in our early ancestors.

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Ancient Egyptian perfume What would be your burial scent?

LEONARD BAUERSFELD

Drone racing AI machines beat humans in a thrilling contest

Video

AI drone racing

An artificial intelligence has outclassed champion drone pilots for the first time. The sport of drone racing involves small quadcopters zooming around an obstacle course while pulling g-forces of up to 5*g*. An AI called Swift achieved a lap time faster than any human. Its makers say their technology could improve the service of delivery drones.

youtube.com/newscientist

Newsletter

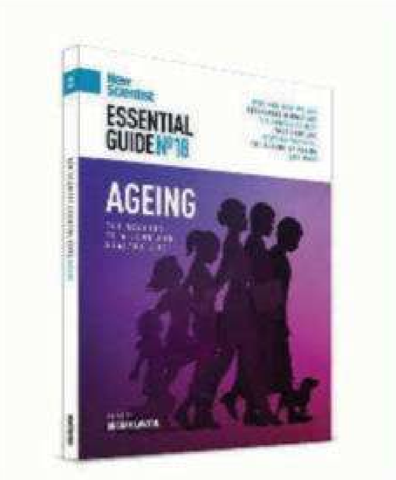
Launchpad

Everyone is vying for the moon. Russia's Luna 25 lander launched on 11 August and promptly crashed. India's Chandrayaan-3 landed on the surface soon after. Japan has plans for a mission too. Leah Crane gets into the long history of moon exploration and what is driving this new space race.

newscientist.com/launchpad

Newsletter

> **"The moon is a jumping-off point for missions to Mars or any other world"**



Essential guide

What drives the ageing process? What can science tell us about the stages of life? And how can we use the latest research to live healthily into old age? This *New Scientist Essential Guide* offers some fresh insight. Available to download in the *New Scientist* app or to purchase in print from our shop.

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An unfinished masterpiece

The joyful challenge of completing our most fundamental picture of reality

THE standard model of particle physics is a stunning achievement. It offers a concise description of the basic constituents of the universe, the particles and forces that make reality, that agrees with every experimental test we have thrown at it. By most measures, it is the most successful scientific theory ever devised.

But as we explore in our special feature celebrating its 50th anniversary, the standard model remains unfinished. It leaves open several profound questions, from the true nature of dark matter and dark energy to why there is more matter than antimatter in the universe.

Physicists are desperately seeking an upgraded version, largely by searching for new particles or forces – or anything in the particles we know of that doesn't fit with the existing theory. So far, they have come up empty-handed.

Some say this leaves particle physics in crisis. But one might equally argue that this is just how this kind of research proceeds, as our brief history of the standard model (see page 33) reveals.

> "There are still many avenues open for us to discover the exotic new physics we are seeking"

It was constructed piecemeal over several decades, through a staccato back and forth between theory and experiment. So perhaps gaps in progress are to be expected, frustrating though they are.

Moreover, there are still many avenues open for us to discover the exotic new physics that would finally take us beyond the standard model – as we explore in the second part of our special (see page 36). Here, six leading physicists share their thoughts on how we will finally complete our brilliant but flawed picture of reality.

Fresh clues might come from the revamped Large Hadron Collider, for instance, which will put the model under even greater strain. We are also expecting final data from an experiment scrutinising the muon, a heavier cousin of the electron, that has hinted at something new. Theorists, meanwhile, are beginning to confront the idea that they might have to rethink their guiding principles.

Put that way, it sounds less like a crisis than possibly the best time to be studying the most exquisite problem in physics. ▮

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Roger Johnston, Axial3D

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BRITAIN & NORTHERN IRELAND

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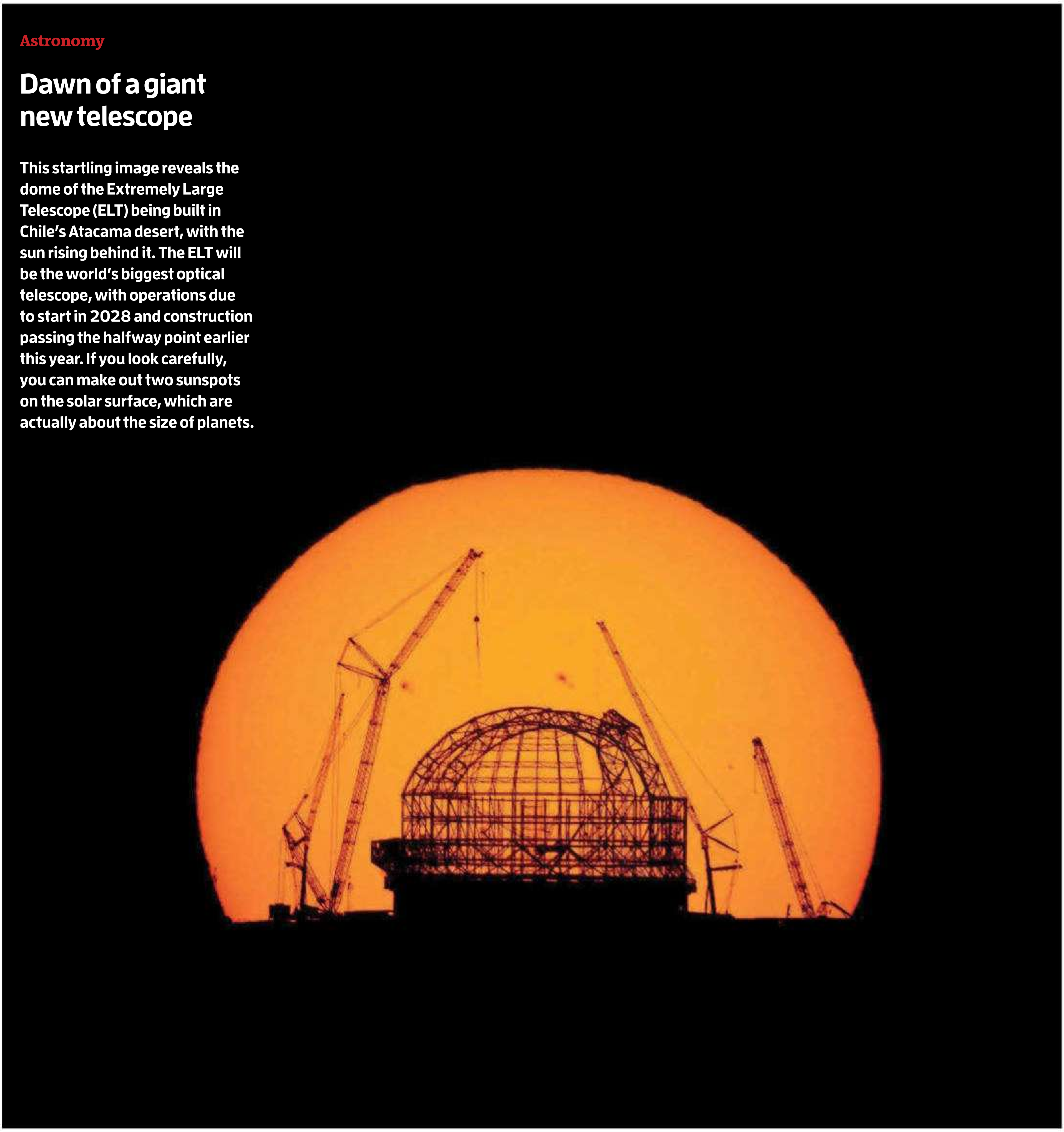
Astronomy

Dawn of a giant new telescope

This startling image reveals the dome of the Extremely Large Telescope (ELT) being built in Chile's Atacama desert, with the sun rising behind it. The ELT will be the world's biggest optical telescope, with operations due to start in 2028 and construction passing the halfway point earlier this year. If you look carefully, you can make out two sunspots on the solar surface, which are actually about the size of planets.



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Palaeoanthropology

Did we come close to extinction?

Genetic analysis suggests that the breeding population of our ancestors fell as low as about 1300 individuals nearly a million years ago, finds **Michael Le Page**

THE population of our ancestors may have plummeted to as low as around 1300 about 930,000 years ago, possibly as a result of our ancestral species splitting from other early humans.

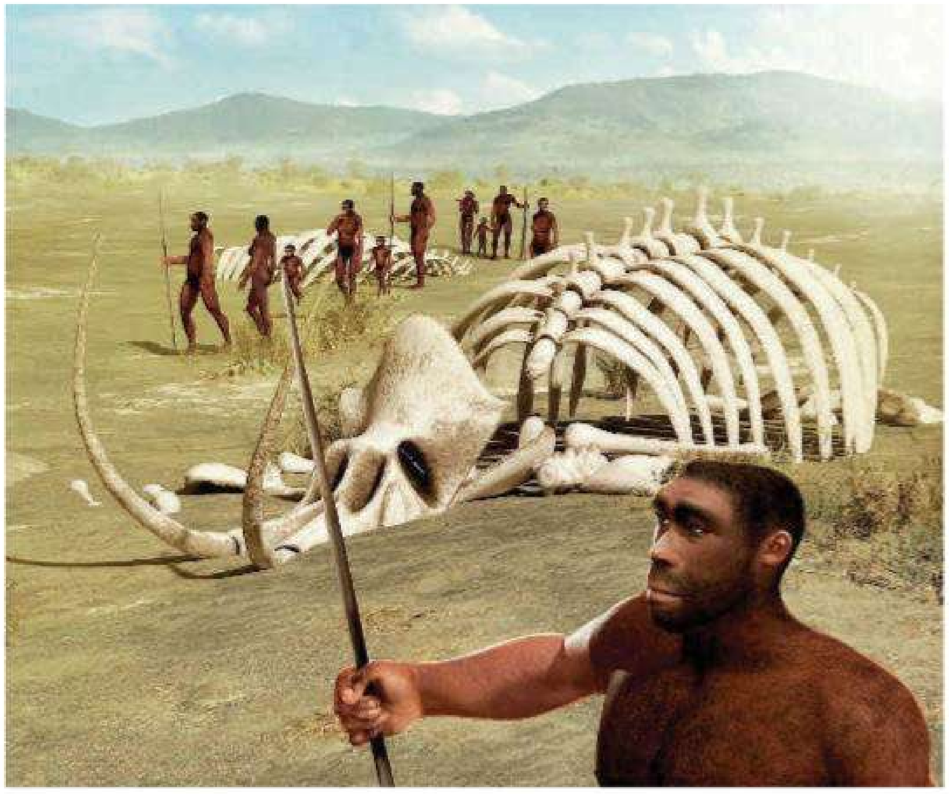
That is the conclusion of an analysis of the variation in the genomes of living people by Haipeng Li at the Shanghai Institute of Nutrition and Health and his colleagues. However, while not dismissing the idea outright, independent experts say it isn't supported by other lines of evidence.

Population bottlenecks occur when an existing population is reduced in size, for instance as a result of a catastrophe or when a small number of individuals leave one population to found a new one. This results in a sudden loss of genetic diversity.

There have been numerous bottlenecks of varying scales as humans evolved and moved around the world. For example, there was a major bottleneck when a small number of modern humans left Africa around 60,000 years ago, which is why there is still much more genetic diversity among people of African descent than in everyone living in the rest of the world combined.

Much more recently, there was a series of bottlenecks as Polynesians settled island after island in the Pacific.

Past bottlenecks can be uncovered by looking for the reductions in genetic diversity they cause, but more ancient bottlenecks are harder to detect than recent ones. Li's team developed a new method for estimating past changes in population size and applied it to the genomes of more than 3000 people from around the world.



SHUTTERSTOCK/OLIVER DENKER

A change in the climate or prey availability could have hit early human populations

According to the researchers' findings, the population of our ancestors fell by 98 per cent to about 1300 "breeding individuals" around 930,000 years ago, and the population remained very low until some 815,000 years ago (*Science*, doi.org/gsnt3b).

The early humans alive at this time have been assigned to a number of different species, including *Homo heidelbergensis*, *Homo rhodesiensis*, *Homo antecessor* and *Homo bodoensis*, and it is unclear which of these is our ancestor. There is also debate about whether they were indeed separate species.

Li and his colleagues think this bottleneck was probably due to climate change, with global cooling around this time leading to severe drought in Africa and Eurasia. This "could explain the extreme scarcity of the available hominin fossil record in Africa and Eurasia" at the time, they write in their study.

930,000

Human populations might have crashed this many years ago

98%

How much the population of our ancestors may have fallen by

Continued habitation

Li says this is referring to previously published studies that have reported a gap at this time. "We didn't find the fossil gap in this study," he says. "Our findings actually explain the fossil gap."

But in an accompanying paper, Nick Ashton at the British Museum and Chris Stringer at the Natural History Museum in London have put together a list of sites in Africa and Eurasia with evidence of continued human habitation during this time.

"The combined evidence, using several independent methods, seems strong," says Ashton. "A global event seems unlikely as this would have affected populations in Eurasia as well as Africa."

"The data of human presence that we marshalled suggest that its effects must have been limited in time and space," says Stringer.

Li's team also cites a paper by Brad Pillans at the Australian National University as evidence of drought in Africa and Eurasia at the time of the bottleneck. "We said nothing about aridity in Africa," says Pillans. "So, in a way, the reference to our paper is not really correct."

John Hawks at the University of Wisconsin, who wasn't involved in the study, points to a paper from earlier this year suggesting that early humans in Africa were split into several distinct populations with only occasional migrations and mergers between them. It is possible that this population structure resulted in the appearance of a bottleneck, says Hawks.

Li's team notes that the timing of the bottleneck coincides with estimates for when two existing chromosomes fused to form chromosome 2. This is why humans have only 23 pairs of chromosomes rather than the 24 of chimpanzees and gorillas.

Another explanation for the bottleneck is that rather than there being a sudden reduction in population due to drastic climate change, it reflects a speciation event where a small number of individuals split away from other early humans after chromosome 2 evolved.

"The possible link to chromosome 2 is very interesting, and I think it may be true. But I would not assume that the bottleneck is real until we have a better understanding," says Hawks. "It would be great to see more ancient DNA data that could get us back into this time period." ▮

A journey to discover black holes
Hear Luciano Rezzolla speak at New Scientist Live on 7 October
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Space exploration

India's moon craft enter sleep mode for the freezing lunar night

Matthew Sparkes

THE groundbreaking lunar exploration mission Chandrayaan-3 has reached its official end point, with India's rover and lander entering "sleep mode" and preparing for sunset and freezing conditions that may destroy their electronic components. But engineers from the Indian Space Research Organisation (ISRO) are confident that the rover will boot up once more when the sun rises on the moon in two weeks' time.

> "Hoping for a successful awakening. Else, it will forever stay there as India's lunar ambassador"

The mission gently touched down its Vikram lander near the moon's south pole on 23 August, making India the first country to explore the region. A six-wheeled rover called Pragyan, which weighs just 26 kilograms, rolled onto the surface and the two solar-powered craft had a single period of daylight – around 14 Earth days – to carry out experiments.

Chandrayaan-3 quickly began providing scientific data from its numerous instruments, including devices on the lander called ChaSTE, which sampled the temperature of the moon dust below the surface, and ILSA, which recorded seismic activity.

The Vikram lander also made a second soft touchdown on the moon in a "hop" experiment, ISRO announced. Engineers on Earth instructed it to fire its engines, lift off to a height of 40 centimetres and move 30 to 40cm laterally before softly landing again. A video of the test shows the tracks left by the rover quickly being obscured by a cloud of moon dust as the engines fire, then appearing slightly further away once the lander had touched down, cut its engines and allowed the dust to settle.

ISRO said that the test "enthuses future sample return and human missions", both of which would require not only a soft landing, but also a subsequent take-off for return to Earth. After the successful hop, the lander redeployed the ramp for the rover and restarted its scientific payloads ChaSTE and ILSA for more measurements.

ISRO

India's Vikram lander is now in sleep mode on the surface of the moon

On 2 September, ISRO announced that the Pragyan rover had covered a distance of 100 metres, having had to adjust course to avoid a crater on its way. Just 8 hours later, it said that the Chandrayaan-3 mission was complete and that the hardware had entered "sleep mode" ahead of sunset, which is expected to bring temperatures as low as -238°C. The scientific payloads were switched off, with all data having been transmitted back to Earth via the lander, and its solar panel was oriented into the best position to start producing power at the next sunrise, which is expected on 22 September.

ISRO didn't respond to a request for interview, but said in a tweet: "Hoping for a successful awakening for another set of assignments! Else, it will forever stay there as India's lunar ambassador."

On 4 September, the organisation announced that the lander – which was some 100 metres from the then-inactive rover – had also entered sleep mode, bringing all operations on the moon to a halt. Both the rover and lander are designed to harvest solar power when available, boot up and resume transmission with Earth, providing their hardware isn't damaged by the cold.

Although the mission was officially only meant to last a lunar day, there is optimism that the hardware will reawaken. Mission operations director M. Srikanth told the *Times of India* at the beginning of the project that engineers were "confident" the rover and lander will revive after the lunar night.

"So far, all margins are looking good and we are confident of the lander and rover coming back to life when night ends. If that happens, that will be a bonus and in case that cannot be achieved, the mission is still complete," said Srikanth. ▮

Probe launches to investigate the mysteries of the sun

Just days after India became the first country to make a successful soft landing near the moon's south pole (see main story), it launched a solar observation satellite to study the sun and the effect of its weather on Earth.

The Aditya-L1 mission will "take India to the forefront of solar space observation" and supply unprecedented data to scientists, says Helen Mason at the University of Cambridge.

The Indian Space Research Organisation launched the satellite on 2 September on a PSLV-XL rocket from Satish Dhawan Space Centre on the country's east coast.

Aditya-L1 is named after both the Hindu sun god and Lagrange point 1 (L1) between Earth and the sun, where the gravitational pull from both bodies is equal.

It will be placed in orbit around L1 so that it can continuously view the sun without obstruction and benefit from the gravitational equilibrium by holding its position without using much fuel. Because the sun is vastly more massive than Earth, L1 is only 1 per cent of the way from Earth to the sun, which are, on average, 150 million kilometres from each other.

The mission objectives include studying why the sun's corona is much hotter than its surface and investigating solar wind and flares. The satellite weighs 1500 kilograms and will carry seven scientific payloads, all developed in India. Four will view the sun and three will carry out measurements of particles and magnetic fields from L1.

Mason says scientists around the world are excited to get their hands on the data once the craft has reached its destination in January 2024.

"This will be unique because it has some instruments which are not carried on other satellites," says Mason. "All the instruments are exciting and they will all push the boundaries of what we have at the moment."

Technology

Implant lets you type by thinking

A company called Synchron may become the first to commercialise a brain implant that lets people control touchscreen devices using just brain signals, discovers **Jeremy Hsu**

RODNEY GORHAM, a 63-year-old Australian, has always been a music fan. In a recent WhatsApp conversation, he told me his most memorable live concert: "AC/DC in their prime". More remarkable than that event is the implant that enables Gorham to communicate despite having amyotrophic lateral sclerosis, which has paralysed much of his body and left him unable to speak.

Gorham was one of the first volunteers to receive a brain implant from a firm called Synchron, an experience he described in the WhatsApp conversation as "exciting". New York-based Synchron is leading the race to commercialise brain-computer interfaces (BCIs), and won regulatory approval from the US Food and Drug Administration to conduct clinical trials in 2021.

To type out his words, Gorham thinks about moving muscles in both ankles. Although he has very limited mobility in his legs and arms, his implant detects the brain signals as he tries to move the muscles, uses computer algorithms to interpret them and then performs the equivalent of a tapping action on a touchscreen device. When this is combined with an eye-tracking system to move the computer cursor, he can digitally tap a desired letter on an on-screen keyboard – although typing out a short phrase can take several minutes.

Synchron has been testing its BCI in two clinical trials. One, called SWITCH, includes four volunteers in Australia, including Gorham; the second, called COMMAND, has five participants in the US. The trials aim to demonstrate how the implant can enable people with paralysis to send texts or emails, do online shopping or banking, control devices such as smart thermostats, or simply ask caregivers for help.

Other start-ups, such as Elon Musk's Neuralink, have joined the race to commercialise BCIs. But Synchron's approach differs from theirs. "There seems to be a feeling in the community that BCI is this tech race to augment the human body," says Tom Oxley, CEO and founder of Synchron. "That's not what needs to happen for the technology to get approved – it needs to first deal with a medical condition that someone has."

Synchron has also shunned open-skull surgeries for brain implants. Instead, the firm uses a less invasive procedure to insert an electrode array, or "Stentrode", into a blood vessel. This is achieved through surgery to the jugular vein, allowing access to a blood vessel near the brain's motor cortex, which controls muscle movements.

> "There seems to be a feeling that making brain interfaces is a tech race to augment the human body"

Oxley says this minimises the risk of complications such as infection to ensure longevity for the implant. Synchron has already shown that the device can operate reliably and safely in a year-long study of the four recipients in the SWITCH trial.

Placing the implant in blood vessels means the electrodes don't have direct access to the brain's neurons. This makes interpreting brain signals like listening to a conversation happening in a room while standing outside the door, says Kip Ludwig at the University of Wisconsin-Madison.

To overcome this, Synchron's engineers have developed algorithms that can interpret poorer-quality brain signals. The firm is now preparing for a third clinical trial to demonstrate that the implant can help people reliably and consistently perform specific functions.

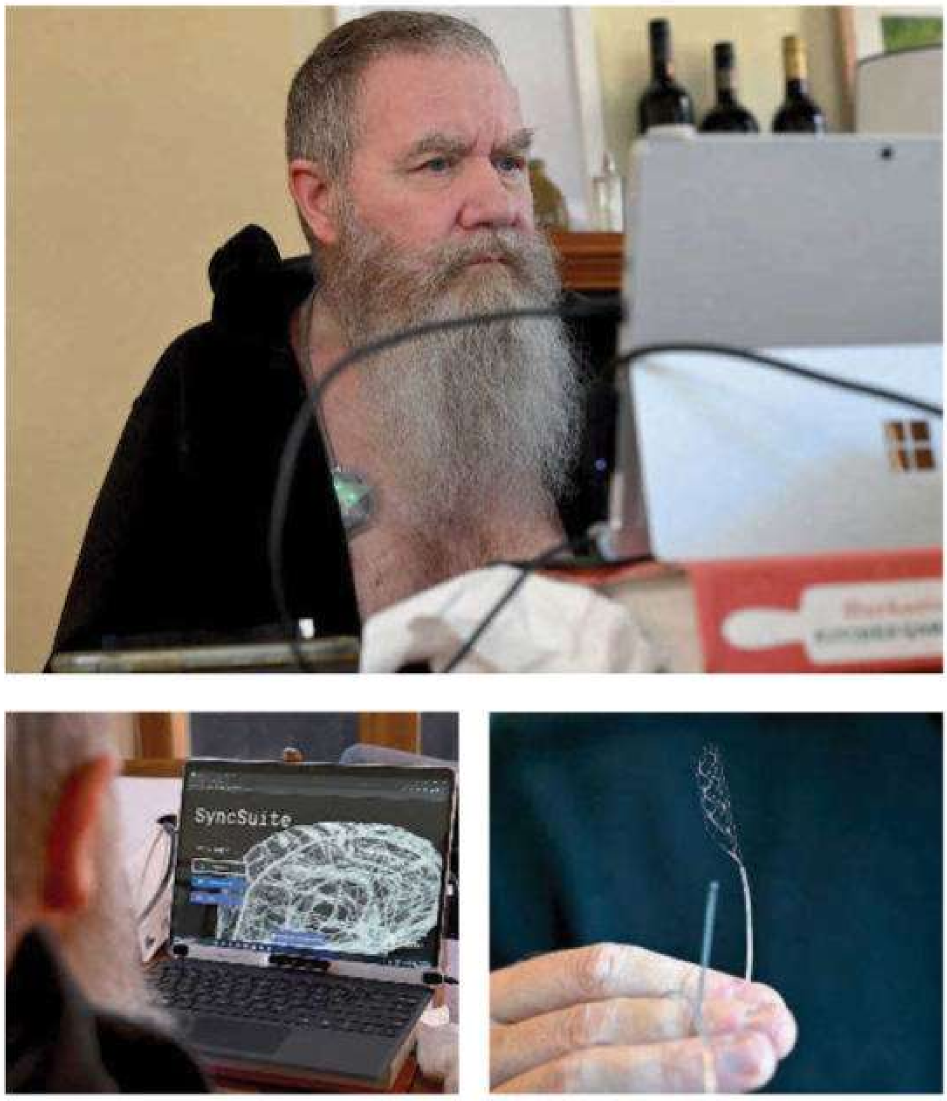
If the trial goes well, Synchron plans to make the implant available commercially. The firm's first target market is the 5 million or so people whose arm paralysis leaves them unable to manipulate a smartphone or tablet.

The BCI will need to show a wider range of command capabilities to be useful for people with less severe movement issues, says Ludwig. For example, the participants in Australia were typing an average of 16 characters per minute with about 93 per cent accuracy last year. That is "better than zero", but "it's not a grand slam home run", says Ludwig.

To get beyond the experimental stage, a brain implant would have to show it can "significantly alter quality of life or quality of care for our patients", says David Putrino at Mount Sinai Hospital in New York, who is overseeing part of the COMMAND clinical trial in the US.

If Synchron can deploy an affordable, reliable device, it could jump-start a market for BCIs, says Nick Ramsey at the University of Utrecht in the Netherlands. It is "a simple system which people can actually use in daily life", he says.

Gorham, too, has words of praise for the technology: "It will save a lot of people who want to communicate with with [sic] the outside world." ▮



WILLIAM WEST/AFP VIA GETTY IMAGES; ANGELA WEISS/AFP VIA GETTY IMAGES

A Synchron brain implant (far right) helps Rodney Gorham use his computer

New Scientist Live
Down to Earth astronomy
Emma Chapman discusses radio telescopes on 7 October
newscientist.com/nslmag

Space

Claims of interstellar meteor fragments in the ocean spark controversy

Leah Crane

TINY metal spheres found on the sea floor may have come from an interstellar meteor. The researchers who recovered the spherules say their compositions don't match anything ever seen before on Earth – but it is a controversial claim.

Earlier this year, Avi Loeb at Harvard University led an expedition off the coast of Papua New Guinea, where models predicted that remnants of an object nicknamed IM1 would have landed. IM1 fell to Earth in 2014. Loeb and his colleagues later identified it as a possible interstellar object based on its recorded velocity, which they claim was fast enough to indicate that it came from beyond our solar system. They hoped to locate its remains on the ocean floor.

During the expedition, the researchers found about 700 tiny, iron-rich spherules, ranging from 0.05 to 1.3 millimetres in diameter. Of the 57 examined so far, five seem to have unusual compositions.

These five orbs are rich in the elements beryllium, lanthanum and uranium, so the researchers have dubbed them BeLaU spherules. The spherules also have low concentrations of elements expected to evaporate in the heat generated by passing through Earth's atmosphere (arXiv, doi.org/kr2m). This indicates that they came from space, yet their compositions aren't consistent with origins on the moon or Mars, or even Earth, says Loeb.

"Usually when you have spherules that originated from meteors in the solar system, their abundances deviate by, at most, an order of magnitude," he says. These deviate by a factor of up to 1000. "If you combine everything that we know… I'm pretty confident that these came from an interstellar object."

The compositions imply the spherules are derived from a planet outside the solar system, whose crust has differentiated, altering how elements are distributed through it, says Loeb.

Not everyone agrees. We would expect interstellar objects to be leakage from clouds of icy bodies not bits of differentiated planets, says Alan Rubin at the University of California, Los Angeles.

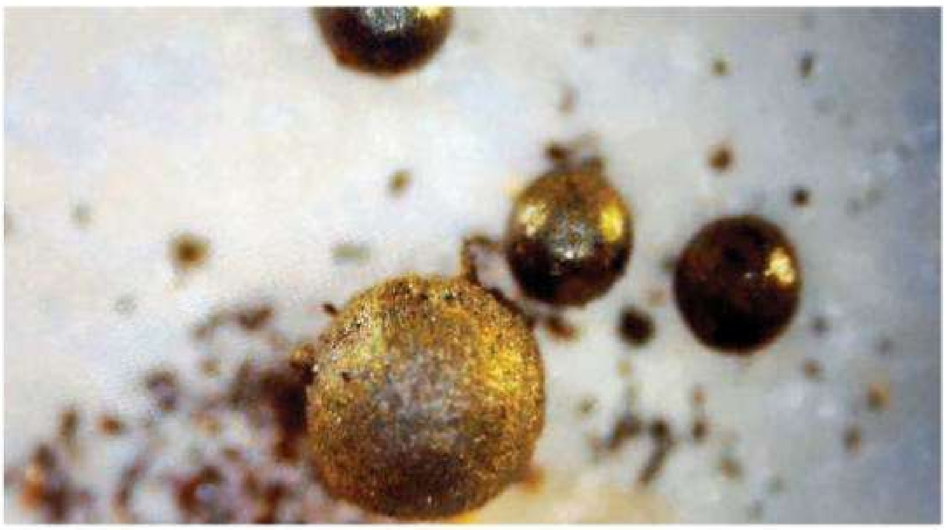
Even the idea that these spherules are novel is controversial. "He'd have to compare them to every rock type on Earth and every mineral composition, and then do the same to every mineral and rock from meteorites," says Matthew Genge at Imperial College London.

"These are things that have been sitting on the sea floor [for] at least nine years, but frankly probably thousands of years, reacting with seawater," says Steven Desch at Arizona State University. "There are natural explanations."

There are doubts over whether IM1 came from outside the solar system, too. There are reasons to think the calculated velocities aren't correct, says Desch. It also isn't clear that material would have survived passing through Earth's atmosphere, he says.

Loeb says more evidence could be available soon, though. "We have only analysed one-tenth of the materials," he says. ▮

Iron-rich spherules collected from the seabed near Papua New Guinea


AVI LOEB

Health

Eczema linked to the diversity of bacteria on skin

THE skin microbiomes of people with eczema seem to feature higher levels of certain bacteria. Gaining a better understanding of this could lead to more effective treatments.

Atopic eczema is one of the most common forms of the condition. This occurs when the skin is unable to retain much moisture, and becomes dry, cracked and itchy. It is thought to have many potential causes and triggers, including certain soaps, cold weather or food allergies.

To see if the skin microbiome has a role in this, Paulo Wender Gomes at the University of California, San Diego, and his colleagues collected skin swabs from 60 people, half of whom had atopic eczema.

The researchers used genetic sequencing to identify the microbial profiles of each participant's swabs.

Overall, those with eczema had a less diverse bacterial make-up than those without the condition. "We observed the diversity of microbes on the skin's surface decreasing in patients with eczema," says Gomes. However, those with eczema had higher amounts of *Staphylococcus aureus* and *Staphylococcus epidermidis*. These bacteria are commonly found on skin and are mostly harmless, but can cause hot, red and swollen skin, such as lumps and blisters.

The researchers also found potentially inflammatory molecules, such as aspartyl-phenylalanine, at higher levels on the skin of people with eczema (bioRxiv, doi.org/kr2q). The molecules have previously been found in some strains of *S. aureus*, suggesting that this bacterium produces them.

"We observed the diversity of microbes on the skin's surface decreasing in patients with eczema"

It is unclear whether changes to the skin microbiome may cause eczema or if symptoms of the condition, such as dryness, alter the microbiome. Further research could lead to treatments that target certain bacteria or their byproducts, suggest the researchers.

Atopic eczema may have genetic links, which research could also explore, says Debajyoti Ghosh at the University of Cincinnati, Ohio. ▮

Sara Novak

Insight

Quantum uncertainty

Why don't we have useful quantum computers yet? Scaling up from initial breakthroughs is proving difficult, finds **Alex Wilkins**

QUANTUM computers have long promised to solve certain problems faster than any ordinary, or classical, computer can. In fact, Google delivered on this promise in 2019, when it declared that its quantum computer had achieved quantum supremacy, performing a calculation impossible for the best classical computers of the day.

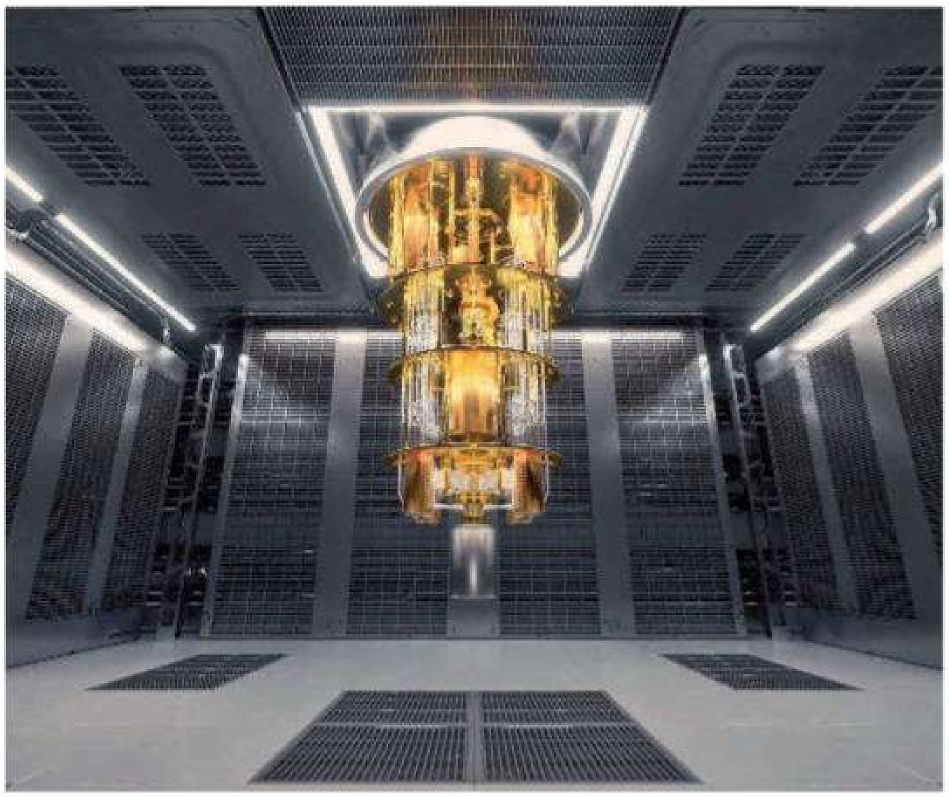
> **"Eventually, the number of qubits will become large enough that no classical algorithm can catch up"**

As *New Scientist* said at the time, Google had "secured yet another place in the history books".

Yet the next chapter of the quantum revolution is struggling to be written. Since Google's breakthrough in 2019, other groups have made similar claims, but in each case improved algorithms for classical computers have reasserted dominance over quantum machines, or at least threatened to. With this back and forth ongoing, will quantum computers ever pull ahead?

While Google's original result appeared to be impossible for classical computers to replicate in any reasonable time frame, in 2022, researchers managed to come up with a new algorithm to do just that. Settling the question of quantum supremacy once and for all will depend on both the number of qubits, or quantum bits, used and the complexity with which they are programmed, referred to as circuit depth. Only when a computer scores high enough on both counts will the results be out of reach for any classical computing or algorithmic improvements.

"Eventually, the number of qubits will become large enough that no classical algorithm can catch up, but it's unclear at which point that is – which is one thing that Google are trying to figure out," says Bill Fefferman at the University of Chicago, Illinois.


JOHN D/GETTY IMAGES

Quantum computers are here, but aren't yet particularly useful

Google's original result demonstrated a task called random circuit sampling, which involves checking that the values of qubits after they have undergone random operations are truly random. It used 54 superconducting qubits for 20 cycles, which refers to how long they perform those random operations, and relates to the circuit depth.

Increased complexity

In April this year, researchers from Google performed this same feat, but with 70 qubits for 24 cycles. Though the increase may seem modest, the jump in complexity is large and, the firm hopes, enough to make the classical-quantum gap more permanent. A calculation on its 70-qubit machine would now take the best supercomputers 47 years to replicate, Google claims.

At the moment, this stands as the best demonstration of quantum supremacy, yet to be bested by classical computers, but these 70 qubits aren't perfect – they are plagued by "noise", which makes it difficult to verify that the computer is fully taking advantage of its quantum nature and isn't vulnerable to classical advancements. Researchers at Google are now working on how they can prove and quantify that the computer is performing a truly quantum task, and how this noise affects that measurement.

So far, they have done this through a benchmark that uses a classical computer to predict the outputs for a quantum machine and then calculates the difference between the final answers. The larger the difference, the more complex the quantum system.

But it was unclear how faithful this measure was to the true nature of the quantum computer and at what point noise made this a useless measurement. Google and, in a separate result, Fefferman and his colleagues have pinpointed the exact level of noise at which we can still effectively use this benchmark for a quantum computer with a certain amount of qubits. "It's really important because it gives us a benchmark by which we can compare, in an apples-to-apples way, successive generations of these experiments," says Fefferman.

Researchers at the University of Science and Technology of China (USTC) have also demonstrated quantum supremacy using 56 qubits of a superconducting quantum computer called Zuchongzhi – a similar kind of hardware as Google's – but they are also working on an alternative quantum computing design that uses photons for qubits. This machine, called Jiuzhang, has demonstrated quantum advantage, but comes with some unique challenges.

Jiuzhang performs boson sampling, which measures a sample of photons that have bounced around a maze of mirrors and beam splitters. Classical computers can't accurately make these measurements above a certain number of photons. Verifying that the measurements are truly quantum isn't straightforward – in fact, a coherent way to do so doesn't currently exist. "The theory to certify these machines is still largely an open question," says Nicolás Quesada at Polytechnique Montréal in Canada.

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Because of this, the researchers' results are vulnerable to classical breakthroughs. USTC claimed its original Jiuzhang result would take 600 million years to verify classically, but in 2022 a group of researchers showed that it could instead be performed in several months, due to a loophole in how the photons were measured by detectors. In April, USTC fixed this loophole by using a new kind of photon detector and reaffirmed its quantum advantage – but without a coherent means to verify this advantage, classical improvements could still chip away at it, says Quesada.

Practical problems

While the USTC team is focused on firming up its quantum advantage and understanding how its machines work, no practical use has yet been found for the quantum advantage itself, though not for lack of trying.

In February, researchers from USTC published a paper exploring how boson sampling might apply to graph problems, which are mathematical problems that can be practically useful for things like drug design and machine learning. "The way that we describe a quantum computer, the kind of mathematical framework that's used to do that, is very similar to other interesting mathematical frameworks," says Naomi Solomons at the University of Bristol, UK.

2019

Year that Google demonstrated quantum supremacy for first time

While the authors concluded that the boson sampling could help perform certain graph problems much faster, they ran into the same verification problem as before and couldn't rule out whether classical algorithms might be able to give the same performance boost.

Mapping real-world problems to quantum computers, and vice versa, will probably make up a large part of research and development in the coming years, says Jay Gambetta at IBM. "We can say that quantum processors are getting to this utility-scale size, but I don't think we are doing enough as a community to work out what circuits we're going to run – I think that problem is as hard as the others."

Gambetta and his colleagues are part of four separate working groups with scientists in other fields looking at how current quantum machines might be applied to scientific problems, for subjects like high-energy physics, materials, life sciences and finance. In July, the first results from the high-energy physics group, following discussions at CERN in Switzerland, were published. Specific problems, such as how particles bounce off each other and how particle pairs separate, were highlighted as having particular promise for quantum machines in the near future.

Instead of marking the point at which quantum computers can be said to finally have advantage over classical machines using benchmarks and mathematical proofs, it might make more sense to define it as when scientists in other fields choose to use quantum computers for their work, says Gambetta. "I think there will be many quantum advantages, but I think when it comes from someone that is not a quantum information scientist, that's when I'm going to care," he says. ▮

Palaeontology

Armoured animal spurs rethink of reptile evolution

Sofia Quaglia

A CHUNKY, 1.5-metre-long predator living some 250 million years ago may alter our ideas about reptile evolution.

Fossils of the novel species – named *Prosaurosphargis yingzishanensis*, because it was found in Yingzishan quarry in China – were unearthed in 2019. The rocks in which the fossils were found indicate that the animal lived in salty lagoons. It was one of the larger marine reptiles on Earth at the time, says Andrzej Wolniewicz at the Hefei University of Technology, China.

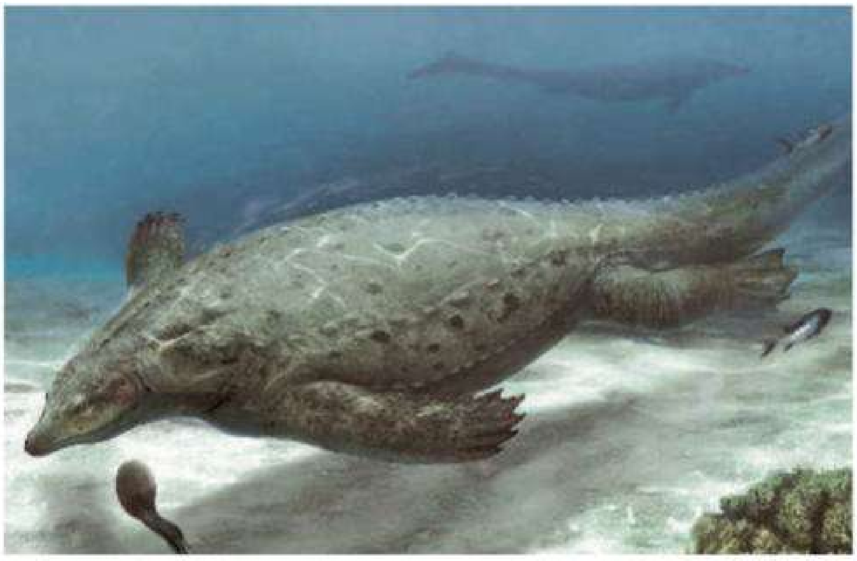
He and his colleagues have analysed the remains and say the reptile probably ate marine invertebrates and small fish. It was well protected from other predators by bony scales and plates, like today's crocodiles, and Wolniewicz thinks the armour may have acted as ballast, enabling the animal to walk on shallow seabeds.

The researchers conclude that *P. yingzishanensis* was a saurosphargid, an extinct family of reptiles a little like marine iguanas. But its unusual body is also similar to that of another group, the sauropterygians, which includes the long-necked plesiosaurs that swam the seas during the age of dinosaurs (*eLife*, doi.org/krsr).

This might warrant a rethink of how these ancient marine reptiles are classified, says Wolniewicz. He and his colleagues suggest we think of saurosphargids as a sub-group of the sauropterygians. "They were actually, you know, one of the early stages of evolution of the group that eventually led to plesiosaurs," says Wolniewicz.

The picture hasn't been clear in part because there was very fast diversification of marine reptiles 250 million years ago in the early Triassic, after the end-Permian mass extinction, says Mike Benton at the University of Bristol, UK. *P. yingzishanensis* helps sort out relationships between them, he says.

The find has implications for living reptiles, too. It hasn't been clear how turtles relate to other reptiles. The evidence from *P. yingzishanensis* helps place them in a large group that includes reptiles and birds – a relationship previously suggested based on DNA analysis, rather than fossils. ▮



The marine reptile *Prosaurosphargis yingzishanensis*

ANDRZEJ S WOLNIEWICZ, YUEFENG SHEN, QIANG LI, ET AL.

New Scientist Live
A history of Britain through burials
Alice Roberts will talk at New Scientist Live on 8 October
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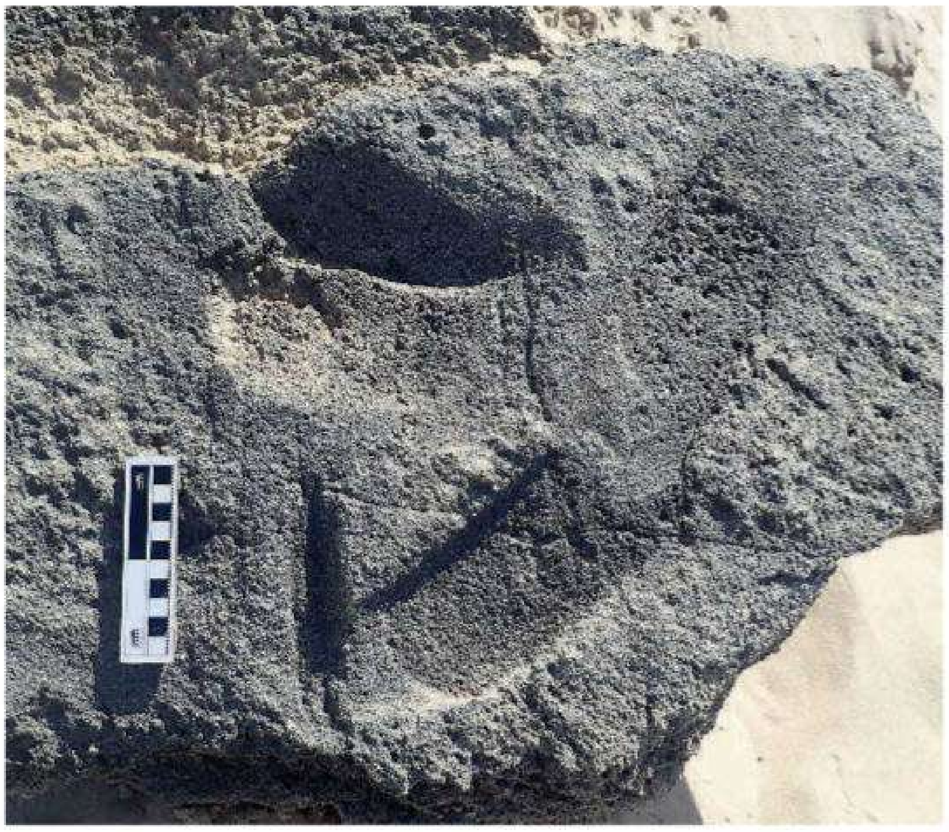
Anthropology

Who wore the first shoes?

Preserved footprints in South Africa suggest ancient humans wore shoes over 100,000 years ago, but pinpointing when it first happened is challenging, says **Michael Marshall**



CHARLES HELM

Possible ancient footprints with shoes at Goukamma in South Africa

HUMANS may have been wearing shoes for well over 100,000 years, and other hominins like Neanderthals may also have had footwear. The suggestion stems from the discovery of unusual preserved footprints in South Africa, which may have been made by people wearing sandals.

"We're not claiming we have conclusive evidence of this," says Charles Helm at Nelson Mandela University in Gqeberha, South Africa. Instead, Helm and his colleagues want to figure out how to reliably distinguish footprints left by bare and shod feet.

Helm's team studied three sites along the southern coast of South Africa, each of which has what appear to be preserved footprints.

One site is at Kleinkrantz in Garden Route National Park. Helm's team found a slab of rock 55 centimetres across. It has at least two well-preserved footprints, plus two other impressions that might be prints.

The two best footprints have extremely clean edges and no sign of details like toes, which is suggestive of shod feet. One of them also has three small divots, which could be where straps were attached to the sole of the footwear.

> **"The items that would have been used to make shoes and footwear would have perished almost certainly"**

In addition, the researchers found a slab of rock in Addo Elephant National Park. It has four tracks, one of which is partial, with no toe marks. They also redescribed a slab of rock (pictured) from Goukamma Nature Reserve, which has four tracks. Three have crisp edges and no signs of toes.

Helm concedes that it is difficult to be sure if the marks are indeed footprints. Normally, human footprints are identified using details like the arch of the foot and the marks left by the toes. "With shod hominin tracks, that's exactly what you're not going to get," he says.

To bolster the case, the team created simple sandals of their own, based on examples of those worn by the Indigenous San people of southern Africa. They glued together two layers of cowhide to make the sole. Then they punched three holes in it, and threaded laces made of cowhide through to make straps.

When a team member walked in these sandals over a wet sand dune, they left footprints similar to those at Kleinkrantz: with no sign of toes or arches, and three small divots per footprint where the straps were attached (*Ichnos*, doi.org/krrm).

"These findings form an important baseline," says Ashleigh Wiseman at the University of Cambridge.

There is some uncertainty over the ages of the trackways. Rocks near the Kleinkrantz slab have been dated to between 79,000 and 148,000 years ago, while samples near the Goukamma slab are 73,000 to 136,000 years old. "It would be good for the sites to be directly dated," says Wiseman.

"I think the authors are very honest, because they don't claim the footprints were made by shod individuals," says Jérémy Duveau at the University of Tübingen in Germany. "They just claim it's a possibility and it's not certain."

A core issue is that prehistoric footwear would have been made of soft materials like leather. "The items that would have been used to make shoes and footwear would have perished almost certainly," says Helm.

As a result, we have very little evidence of shoes in the archaeological record, says Duveau.

The oldest known items of footwear are sandals found in Fort Rock cave in Oregon, dated to just 9200 to 10,500 years ago. More recent examples include a shoe from Areni-1 cave in Armenia that was dated to 3377 to 3627 BC.

Reshaped bones

There are also a handful of sites where researchers have identified footprints like those in South Africa, which look like they were made with shoes. In a 2021 study, researchers led by Lysianna Ledoux, then at the University of Cantabria in Santander, Spain, identified apparent shod footprints in Cussac cave in south-west France. The tracks were 28,000 to 31,000 years old.

Another 2021 study found similar footprints in Theopetra cave in Greece, close to 135,000-year-old rocks. If the tracks are similarly old, they may have been made by shod Neanderthals.

Finally, some researchers have looked for other kinds of evidence. Erik Trinkaus at Washington University in St. Louis, Missouri, has published studies of human foot bones, which he argues have been subtly reshaped by wearing footwear since as early as 40,000 years ago.

Others have examined the tools people used, in a bid to find out when the equipment needed to make footwear – and clothing in general – was available.

The data points are scattered in both time and space, so it isn't currently possible to reconstruct prehistoric peoples' footwear habits, says Helm. All we can say is that evidence of footwear seems to be confined to the past 140,000 years or so. "I don't think we're going further back than that," he says. ▮

Health

Excessive vitamin C and E intake may speed lung cancer growth

Jason Arunn Murugesu

TAKING antioxidant supplements such as vitamins C and E may cause lung cancers to grow bigger and spread by stimulating the formation of blood vessels within tumours, according to a study in mice. One researcher involved has said that people with lung cancer shouldn't try to avoid these antioxidants in their diet, but getting more than they need via supplements could cause harm.

Martin Bergö at the Karolinska Institute in Sweden and his colleagues previously found that supplementing with the antioxidants vitamin E and n-acetylcysteine caused lung cancers to spread in mice.

To better understand how this might occur, Bergö and a different team of researchers studied mice with a murine-specific form of lung cancer and mice that had been implanted with human lung cancer cells. They supplemented the mice's water with vitamin C, which the animals naturally produce, and vitamin E and n-acetylcysteine, which they get from their diet.

The supplements were given at increasing doses, which made the levels of these antioxidants in the mice exceed what was necessary. "Today in society, you have a lot of people who eat healthily, they have some supplements, and then they may have a ginger shot and a smoothie," says Bergö. "If you do all that, you could end up with the levels of doses that we're talking about."

The researchers found that the higher the antioxidant doses, the greater the rate of blood vessel formation in the tumours. This was true for mice with the murine lung cancer and those with implanted human cancer cells. Increased blood vessel growth would probably lead to tumours growing and spreading, says Bergö, but they didn't study this.

Bergö has stressed that people with any form of cancer shouldn't alter their diet on the basis of this research. "If you took away all the antioxidants in food, you would get sick for a range of reasons, such as vitamin deficiencies, and this would influence the cancer," he says. "We're focusing on increased doses above the required levels."

> "The higher the antioxidant doses, the greater the rate of blood vessel formation in the tumours"

The researchers also studied human and mouse lung cancer tumour organoids, balls of cells grown in a lab. After exposing them to higher-than-necessary doses of the three antioxidants, they found that these neutralised so-called free oxygen radicals within the organoids.

In the previous research, Bergö and his team implicated a protein called BACH1 in increasing tumour growth following vitamin E and n-acetylcysteine supplements. The new work suggests that BACH1 is activated when there is a drop in free oxygen radical levels, which induces blood vessel formation (*The Journal of Clinical Investigation*, doi.org/gsntwg).

The findings could point the way to altered cancer treatments, says Bergö. Blood vessel growth inhibitors are used in cancer therapy, but can have severe side effects, such as blood clots, he says. They might be more effective in people who have high levels of BACH1 in their tumours, which can be screened for, he says.

The researchers also found that elevated BACH1 levels were often associated with kidney and breast tumours in genomic databases, so these conditions could also be targeted via blood vessel growth inhibitors in people with high BACH1 levels, says Bergö. ▮

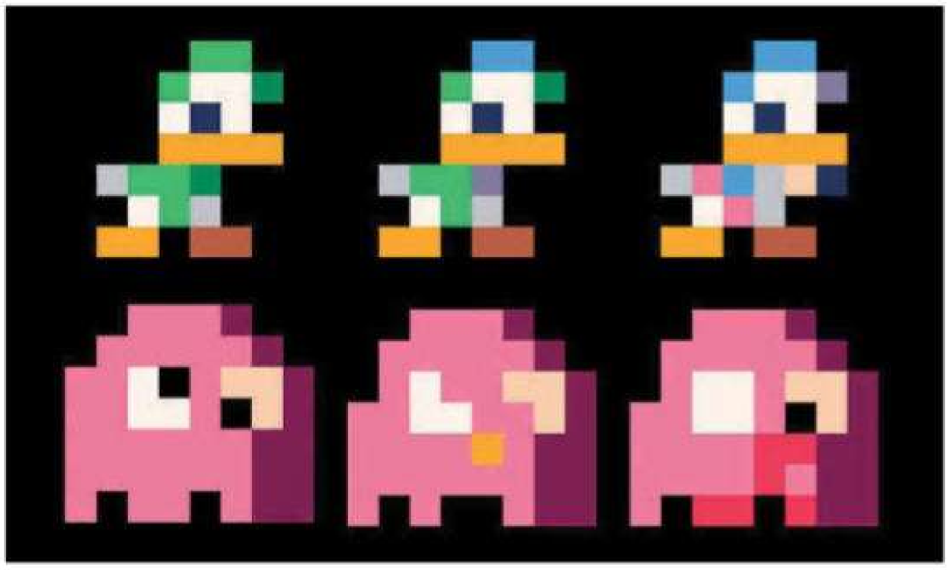
Artificial intelligence

AI generates game characters and levels from text prompts

A SIMPLE AI tool can create video game maps, character models and emojis from a single-sentence prompt within milliseconds.

Julian Togelius and Timothy Merino at New York University and their colleagues designed the system as a way of understanding how simple an AI model can be while still proving useful.

They trained their model on databases of 882 game maps, 100 game sprites and 10,000 emojis, all of which were labelled with descriptions. "All of our datasets were fairly small, and that was by design," says Merino.



TIMOTHY MERINO ET AL./JOHAN VINET

"Duck" and "ghost" character sprites created by an AI

The labels didn't give the names of characters, instead describing the eponymous Mario as "a man with a moustache dressed in red", for example. Alternative labels were also created to train the model using GPT-4, the large language model behind ChatGPT.

The AI model itself uses a simplistic neural network that removes many of the modern developments that are powering the current generation of AI. For example, the network doesn't include any feedback loops, meaning the information flows in one direction, from input to output.

Despite its simplicity, the AI was able to generate accurate depictions of what was asked via text prompts, such as "a grassy field with some flowers" or "an island of trees in the river" (arXiv, doi.org/kr2f).

The model shows what can be done with limited computing power, says Togelius. "This thing is trained on your home computer and runs on your phone, basically, in blazingly fast time." ▮

Chris Stokel-Walker

Technology

AI beats champion human pilots in head-to-head drone races

Matthew Sparkes

AN ARTIFICIAL intelligence has consistently beaten champion drone pilots in races for the first time, achieving lap times no human was able to match. The technology could be used to speed up drones doing everyday tasks.

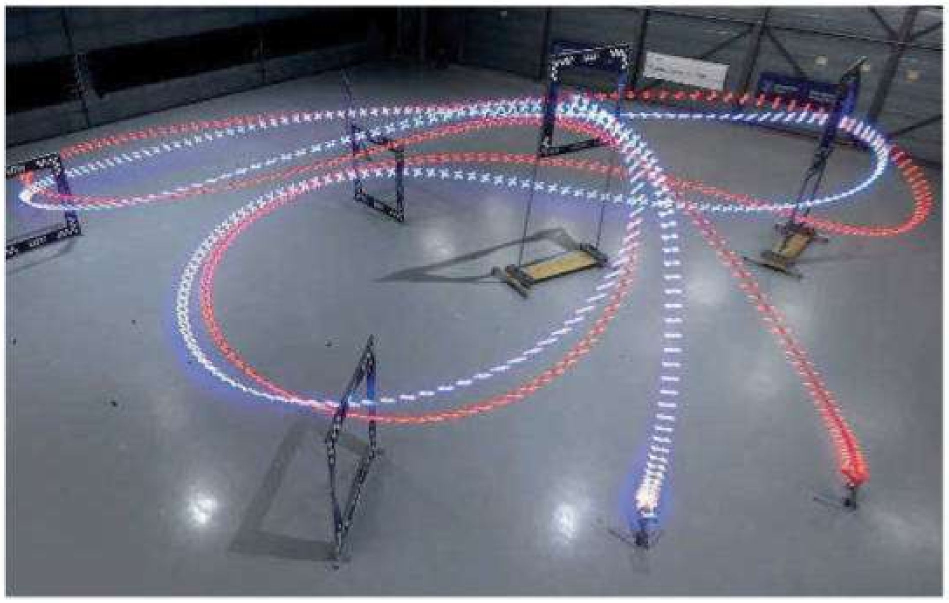
The sport of drone racing involves humans piloting small quadcopters around a course at speeds of more than 100 kilometres per hour, with the vehicles subject to g-forces of up to 5 *g*. The drones fly through a series of gates in a set direction and order, and the people steering them wear headsets streaming video from cameras on the drones.

Leonard Bauersfeld at the University of Zurich in Switzerland and his colleagues have created an AI called Swift to compete in these races. It raced against three top-level human pilots – including Alex Vanover, the 2019 Drone Racing League world champion – and won 60 per cent of the time.

Human pilots were given a week to practise on the specific race track and Swift was also allowed to train on it before they raced. The AI won 15 out of 25 races and achieved the fastest recorded time over the course, beating the closest human time by half a second (*Nature*, doi.org/gsnqj9).

Bauersfeld says AIs have only beaten human performance in drone racing before when they have benefited from dozens of cameras placed around the course and an external computer transmitting instructions to the drone in real time. “That’s a bit of an unfair advantage,” he says.

> “The AI won 15 out of 25 races and beat the closest human time by half a second”



An AI (blue) races against world champion Alex Vanover (red)

LEONARD BAUERSFELD

Swift uses only a single camera and a computer, both of which it carries, making it a totally encapsulated system. Bauersfeld says Swift is designed to fly at about 99.5 per cent of the speed it could manage, to leave a safety margin and improve reliability.

Swift is also unusual in that it fuses AI and classical computer algorithms. First, an AI takes video from its camera and identifies where the gates are. Then, a classical algorithm determines the drone’s orientation and position given those gate locations. Another AI takes that data and determines where the drone should fly next and what control inputs are needed to achieve that. “We fuse the two [computational approaches] in order to get something that is better than just one,” says Bauersfeld.

Guido de Croon at Delft University of Technology in the Netherlands says the work is impressive as the drone carries the sensors and computer power. AIs that have beaten people at other games, such as Go or *StarCraft*, could use unlimited computing power and operate virtually, with people moving pieces for them in the physical games.

De Croon says few applications require the high speeds involved in these experiments – outside possible military use – but the work will have applications. “You do need to fly faster than drones have been flying. If you fly slowly, you waste your battery,” he says. ▮

Animal behaviour

Pirate spiders lay traps to ambush other arachnids

A SPIDER species in Costa Rica has a unique hunting strategy, attacking other spiders that use its silk lines as scaffolding for their own webs.

Many spiders build webs to snare prey. Some webs are flat sheets, while others form tube-like funnels or spiralling orbs. Other species forgo webs and instead chase or ambush prey.

Of the roughly 200 documented species of pirate spiders, most follow the same general hunting plan: they pluck strands of another spider’s web to mimic a trapped insect. When the owner comes to investigate, the pirate spider sneaks from its hiding place and strikes. Typically, “they walk subtly onto a spider web and attack the spider when it’s in reach”, says Laura Segura-Hernández at the University of Nebraska-Lincoln.

She and her colleagues have discovered that the species *Gelanor siquirres* in Costa Rica seems to have a different strategy.

ROMAN WILLI/NATUREPL.COM

A pirate spider resting on a leaf in Osa peninsula, Costa Rica

The researchers found webs built by six *G. siquirres* spiders, each with long, dry silk lines that extended down from plants to the forest floor.

These roughly 2-metre-long lines are tempting scaffolding for web-building spiders, which try to attach their floating lines to the dry silk at night. When the pirate spider senses the vibrations, it drops down from its roost to attack (*Animal Behaviour*, doi.org/krq7).

“It was surprising to be able to record a whole new behaviour, and on a species that we know nothing about,” says Segura-Hernández. The strategy could be particularly effective in a tropical rainforest that hosts lots of nocturnal web-building spiders, which begin to build their webs at twilight, she says. ▮

Corryn Wetzel

New Scientist Live
Ultra-processed food
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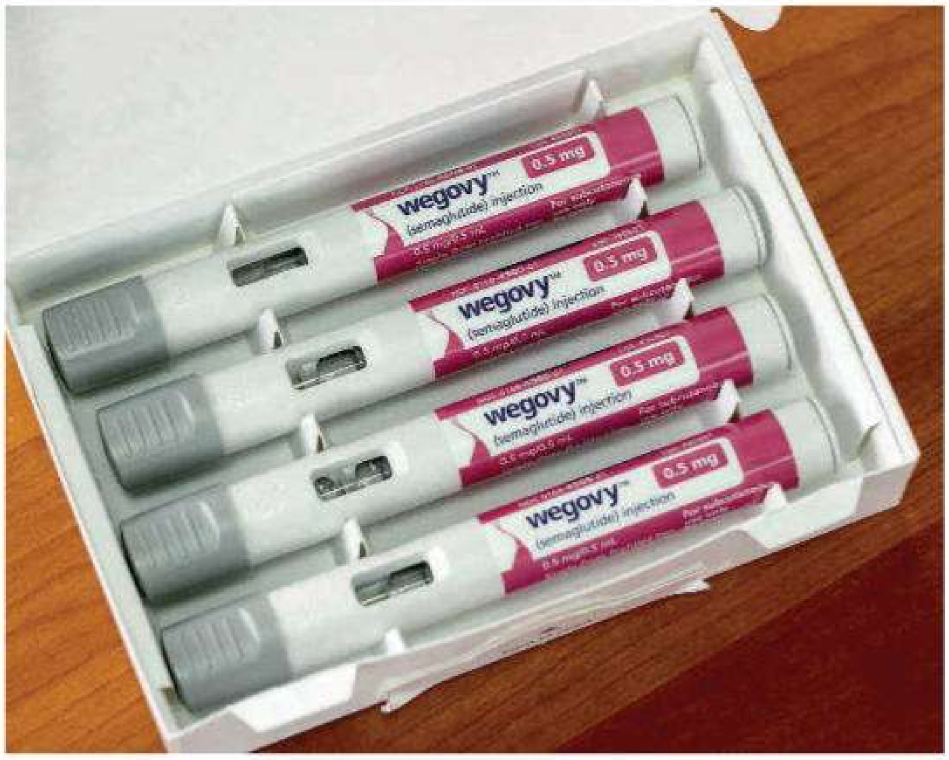
Why is the Wegovy weight-loss treatment so hard to get hold of? Drug-maker Novo Nordisk is struggling to meet demand for its weight-loss treatment, and the drug's price in the US may be why it hasn't launched more widely, says **Clare Wilson**



JIM VONDRUSKA/REUTERS

Wegovy, delivered by injection, is only available in a few countries so far

THE weight-loss injection Wegovy is one of the most successful new pharmaceuticals, but many people who want it can't actually access it.

In most countries in Europe, Wegovy hasn't yet been launched, despite expected high demand. In the US, one of the few places where it is available, manufacturer Novo Nordisk has been trying to limit the number of people who start taking the medicine.

This isn't the usual behaviour of a pharmaceutical company with a recently approved medicine expected to generate blockbuster sales. So why is Wegovy so hard to get hold of?

The answer may lie in the fact that semaglutide, the active ingredient in Wegovy, is so resoundingly effective for weight loss. Scientists have been trying for decades to develop a weight-loss drug that is safe to take long term. Semaglutide, which works by mimicking a hormone called GLP-1 that is released after eating, was initially approved as a treatment for type 2 diabetes, branded as Ozempic.

Significant weight loss

But semaglutide also causes people to lose significant weight – enough for many users to shift from an obese to a "healthy" body mass index. As word of these effects spread, people without diabetes began using Ozempic "off label" for weight loss, jeopardising supplies for people with diabetes who need it for blood sugar control.

Wegovy was approved explicitly for weight loss by the US Food and Drug Administration in 2021. Like Ozempic, to minimise side effects, people start off on a low dose and this is gradually increased until the maintenance dose is reached. The two products contain the same drug, but the Wegovy maintenance dose is slightly higher.

Launching Wegovy in the US first makes economic sense, as the US has one of the world's heaviest populations. It is also the world's biggest market for pharmaceuticals due to its large population size and the fact that drug prices there are generally higher, as there is no centralised system for healthcare providers to negotiate prices directly with manufacturers.

$1349

List price for Wegovy per month in the US

$300

Price of Wegovy per month in two European countries

$413bn

Stock market valuation of Novo Nordisk, which makes Wegovy

As an indication of just how distorted US drug prices are, the US list price for Ozempic is $936 a month, compared with around $100 in most other countries, according to a report published last month by health analysts Peterson-KFF.

The US list price for Wegovy is $1349 a month, compared with about $300 in the two European countries included in this report. US healthcare providers may negotiate discounts on drug list prices, but are still paying several hundred dollars a month more than what is paid in Europe, says Cynthia Cox, one of the report authors.

Despite the prices, demand for Wegovy and Ozempic in the US has been so strong that Novo Nordisk has struggled to meet it. The firm said in May that, in the US, it would limit availability of the lower starting doses of Wegovy to ensure that those already taking the higher maintenance dose wouldn't have their supplies interrupted.

Soaring valuation

Novo Nordisk's income from US sales of semaglutide has been so high that it has seen its market valuation soar by 38 per cent in the year to mid August, to $413 billion – more than the 2022 gross domestic product of Denmark, where the company is based. The influx of billions of dollars a year from US sales has strengthened the Danish kroner and forced Denmark's central bank to lower interest rates.

Cynics might argue that the huge sums Novo Nordisk is making in the US explains why it has lagged on launching Wegovy elsewhere. In England, for instance, one of the few countries to agree to public funding of Wegovy treatment through a national health system, the product was initially set to be available by spring 2023, but this was delayed, and limited stock only arrived at the start of September.

A spokesperson for Novo Nordisk says: "We are actively producing and shipping all dose strengths. However, demand continues to outpace our increasing production. As a result, we anticipate ongoing supply disruption."

They add that Wegovy for the US market is being manufactured in a different injection device to other markets and therefore isn't affecting supply elsewhere. They say that while they couldn't give information about launch dates, the firm is working to make Wegovy available in the UK as soon as possible.

But it is possible that even after an official launch, people still may find it hard to fill their doctor's prescriptions. It seems that the world's appetite for weight-loss drugs is insatiable. ∎

Technology

Virus nanobots make harmful bacteria glow

Karmela Padavic-Callaghan

GENE-edited bacteriophages, or viruses that attack bacteria, can make pathogens in food and water glow so they are easier to detect.

In the US and UK, drinking water must contain no *Escherichia coli* bacteria, which can cause food poisoning. Existing methods of testing water for such bacteria can be time-consuming or unreliable at low microbial concentrations.

Sam Nugen at Cornell University in New York and his colleagues have now tried using bacteriophages as "nanobots" to help. These viruses infect bacteria by injecting DNA, making them create copies of the virus. The researchers used the gene-editing tool CRISPR to make two alterations to bacteriophage DNA, the first causing infected *E. coli* to produce a glowing compound. The second tweak changed the structure of the viral duplicates made by the *E. coli* so they would stick to cellulose film or magnetic particles. This meant the detected bacteria could be removed.

In experiments with spinach leaves liquefied by enzymes and with water collected from a local municipal source, the gene-edited bacteriophages were sensitive enough to detect as few as five bacteria in 100 millilitres, Nugen told an American Chemical Society meeting in San Francisco last month.

Vivek Mutalik at the Lawrence Berkeley National Laboratory in California says that using bacteriophages is advantageous because they work quickly, and there are those that specialise in finding and attacking most bacteria. However, he says, bacteriophages may specifically target one type of bacteria, when it would often be helpful to detect many types at once.

Nugen said his team has already made bacteriophages that aid the detection of other bacteria, including *Listeria* and *Salmonella*. ▮

Astronomy

Massive crater found on a distant world beyond Neptune

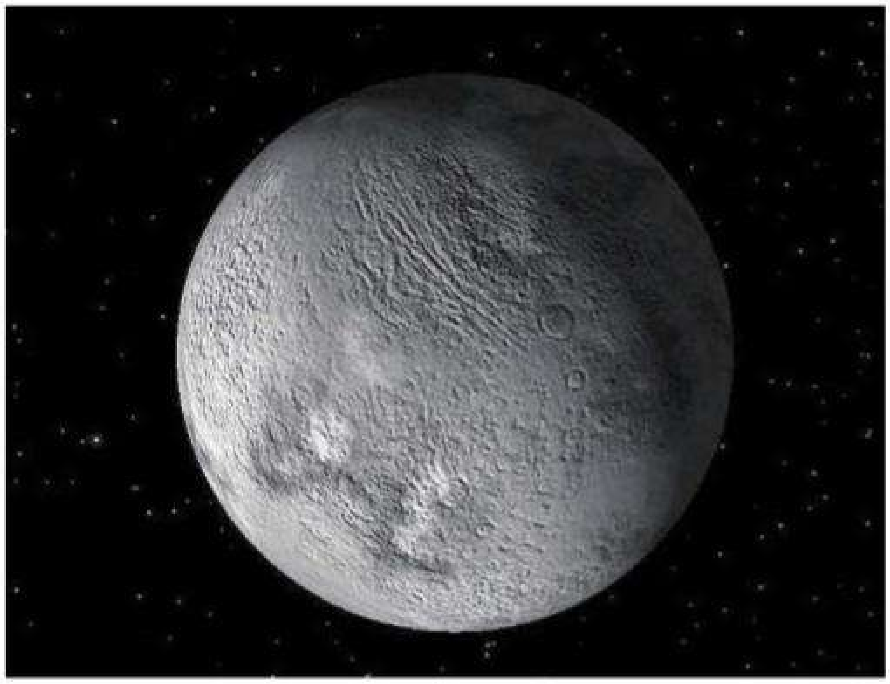
Jonathan O'Callaghan

AN OBJECT in the outer solar system appears to have had a huge chunk taken out of it in a violent collision, despite such impacts being rare at this distance from the sun.

Flavia Rommel at the Federal University of Technology in Brazil and her colleagues enlisted the help of hundreds of amateur astronomers to study the distant world 2002 MS4, found beyond Neptune's orbit in the Kuiper belt. The so-called trans-Neptunian object (TNO), discovered in 2002, is so remote that it can barely be seen by telescopes, despite being some 800 kilometres wide.

Rommel and her team used a technique called occultation to study the object in more detail, recruiting telescopes from around the world to watch as it passed in front of a background star in 2020, blocking the star's light. That let them refine the size and shape of 2002 MS4, but also threw up a surprise.

An artist's impression of 2002 MS4, made before the new measurements



EXOPLANET EXPERT/CC-BY-SA-4.0

"It was not round in the north-east region," says Rommel. The researchers concluded that they were seeing a massive depression in the object, probably a crater, around 45 kilometres deep and 320 kilometres across (arXiv, doi.org/krnm). "This is the first example of a large crater beyond Neptune," says Rommel.

The rim of the crater appears to rise about 25 kilometres above the surface of 2002 MS4, which would make it taller than Olympus Mons on Mars, the biggest mountain in the solar system. Only once before have we seen anything like this vast feature on a world so far from the sun, a deep crack twice the size of the Grand Canyon on a TNO called 2003 AZ84.

Team member Bruno Sicardy at the Paris Observatory in France says the depression was "quite unexpected", adding that there is "no other body which is 800 kilometres with such a large topographic feature".

However, it is possible that the feature isn't a crater, but actually a moon orbiting the TNO, which would distort its apparent shape. That explanation is unlikely, says Sicardy, requiring "a lot of luck", but can't be ruled out yet.

320km

The diameter of a giant crater on distant world 2002 MS4

No other telescope – not even NASA's James Webb Space Telescope (JWST) – can observe 2002 MS4 in as much detail as the occultation technique because the object is so far away, around 40 times as distant from the sun as Earth is. However, JWST could help confirm the existence of any orbiting moon.

If the feature is a giant crater, it would point to a violent collision involving this object at some point. Such collisions are common closer to the sun, but rare at this distance, where objects are more spread out. "This was not expected," says Rommel.

The discovery could give us a unique window into our solar system's evolution, says Alex Dias de Oliveira at Avenues: The World School in São Paulo, Brazil. "These objects work as fossils for the solar system because they are so far from the sun," he says. "Knowing their shape will give us more information about their chemical composition. If you understand their composition, you understand the past of the solar system." ▮

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Archaeology

Egyptian mummy's scent analysed

A BALM used while mummifying an ancient Egyptian noblewoman, who died 3500 years ago, smells like beeswax, bitumen, plant oil and tree resin, say Barbara Huber at the Max Planck Institute of Geoanthropology in Germany and her colleagues.

Using gas chromatography-mass spectrometry, the team unpicked the chemicals in residue found in jars that held the organs of the woman, Senetnay, who was buried in the Valley of the Kings. Huber calls the extracted perfume "the scent of eternity" (*Scientific Reports*, doi.org/krr3).

The analysis suggests the balm contained resin from trees not naturally found in Egypt, hinting that ancient Egyptians were importing goods from far away earlier than previously thought. **Sofia Quaglia**

ANATOLII STEPANOV/AFP VIA GETTY IMAGES

Drugs and alcohol

Alcohol may not give you 'beer goggles'

CONTRARY to popular belief, people may not get "beer goggles" after a few drinks, though alcohol may encourage them to approach others they already find attractive.

Molly Bowdring at Stanford University, California, and Michael Sayette at the University of Pittsburgh, Pennsylvania, studied 36 heterosexual men. Drinking a cocktail of cranberry juice and vodka, equivalent to about three standard-strength vodka-based drinks, didn't affect how the men rated the attractiveness of 16 women. However, they were almost twice as likely to say they wanted to meet those they considered most attractive compared with when they had been drinking just cranberry juice (*Journal of Studies on Alcohol and Drugs*, doi.org/krr5). Alcohol may reduce our fear of rejection, say the researchers. **Chen Ly**

Technology

Earthquake sensors track bomb attacks in Ukraine

SEISMOMETERS in Ukraine – normally used to detect earthquakes or monitor nuclear weapons tests – have been used to detect the times and locations of more than 1200 explosions in provinces near Kyiv. The estimates of explosive power also provide clues about the ammunition or weapons behind each blast.

"We're automatically processing data and seeing explosions almost as they happen," says Ben Dando at NORSAR, a seismic research foundation in Norway. "That has never been done in an active conflict in real time before."

Dando and his colleagues started by looking for unusual explosions near Ukraine's nuclear power plants in February 2022. They soon realised they were picking up a variety of explosions as battles raged and Russian airstrikes hit Ukrainian cities (pictured).

Using existing software and techniques, they set up detection algorithms that could automatically provide alerts within 10 to 15 minutes of an explosion. The algorithms can calculate the location and timing of explosions based on when different seismic waves arrive at nearby sensors (*Nature*, doi.org/krrv).

Seismic monitoring could help track the number, timing and sizes of explosions, but the estimates may not yet be precise enough to definitively identify the particular weapon involved, says Michael Pasyanos at the Lawrence Livermore National Laboratory in California. Monitoring of conflicts would also be more difficult in the Middle East, Africa and South America, where there are relatively few seismic arrays, says Pasyanos. **Jeremy Hsu**

Really brief

VINÍCIUS C. CLÁUDIO

Bat spotted for first time in a century

After more than 100 years, a missing Brazilian bat is back. The strange big-eared brown bat (*Histiotus alienus*) hadn't been seen since being described by scientists in 1916, but a bat collected in 2018 in a Brazilian grassland has become only the second known specimen (*ZooKeys*, doi.org/krrp).

Running shoe heels may raise injury risk

Shoes with a higher heel may raise the risk of running injuries by changing how feet strike the ground. Running shoes with heels about 20 millimetres high may be more likely to cause discomfort and tightness in the lower legs than those with little or no heel (bioRxiv, doi.org/krrq).

US consumption of beef is skewed

About 12 per cent of people in the US are responsible for half the beef consumption there, according to a survey of more than 100,000 adults. Men and people who identified as white or Hispanic were more likely to eat disproportionate amounts of beef (*Nutrients*, doi.org/gsnq5p).

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Culture columnist
Simon Ings learns the dark lessons of *Billion Dollar Heist* p30

Comment

Defining the Anthropocene

I resigned from the Anthropocene Working Group because our global impact began long before the arbitrary date chosen, says **Erle Ellis**

SIMONE ROTELLA

FROM rapid climate change to biodiversity loss, the Anthropocene marks our times as an age of human-caused planetary disruption. A working group of the International Commission on Stratigraphy now proposes to more precisely define the Anthropocene, a term originated by Paul Crutzen and Eugene Stoermer in 2000.

Using the methods that demark all units in Earth's official history book, the geologic time scale, the group would define the Anthropocene as an epoch of geological time starting precisely in 1950, marked by plutonium isotopes from nuclear weapons fallout in the sediments of Crawford Lake in Canada.

People familiar with the term might find this a strange choice of timing. Automobiles and even the atomic bomb are thus relegated to a prior epoch, the Holocene, which began at the end of the last glacial period, 11,700 years ago (marked by a rapid shift in deuterium in a Greenland ice core). Defining planetary change in relation to a single lake is also hard to parse.

Whatever one's perspective, defining an Anthropocene Epoch could seem an arcane matter best left to the experts. But nothing could be further from the truth.

I joined the Anthropocene Working Group in 2009, inspired by an article entitled "Are we now living in the Anthropocene?" Many good years of scientific collaboration followed. Even as an ecologist with differing perspectives from the geologist majority, I generally found my contributions welcome.

In 2016, all this began to change with a vote deciding that only evidence supporting a mid-20th century start date would be considered in defining the Anthropocene. I probably should have resigned then. I cast a dissenting vote. Broader discussions continued. But the path was set. Now, the group brooks no dissent in promoting a 1950 Anthropocene. I resigned in protest in July, after two others.

Dividing Earth's human transformation into two parts, pre and post-1950, does real damage by denying the deeper history and the ultimate causes of Earth's unfolding social-environmental crisis. Were the changes wrought by industrial and colonial nations before 1950 not significant enough to transform the planet? The political ramifications of such a misleading and scientifically inaccurate portrayal are clearly profound and regressive.

Human transformation of Earth's ecosystems, biodiversity and climate began long ago, and expanded dramatically through five centuries of European colonialism. Industrial greenhouse gas emissions in the "latter part of the 18th century" were Crutzen's Anthropocene inspiration and he noted that a more precise start would be "arbitrary". I couldn't agree more.

Evidence for unprecedented anthropogenic planetary change is overwhelming. It readily speaks for itself. If a geological definition is needed, the Anthropocene is easily defined as a complex, transformative and ongoing geological event analogous to the Great Oxidation Event and others in the geological record.

Choosing to systematically ignore the overwhelming evidence of Earth's long-term anthropogenic transformation isn't just bad for science, it is bad for public understanding of the causes of these changes and for action to address them. This, when broader cooperation to tackle these grave societal challenges is more critical than ever.

There is no need for a precise start date for the Anthropocene. There is no benefit, scientific or otherwise, to defining the human age in a shallow band of sediment in a single lake. And, most importantly, there is no need for a divisive narrative, with the mantle of scientific authority claiming that the age of human-caused planetary change began in 1950. ▮

Erle C. Ellis is a professor at the University of Maryland, Baltimore County, and author of *Anthropocene: A very short introduction*

Health Check

The alternative view The WHO caused an uproar when it held a summit on complementary medicines. We need evidence about the risks and benefits of these therapies, says **Clare Wilson**

Clare Wilson is a reporter at *New Scientist*. She writes *New Scientist*'s weekly email newsletter Health Check, about the latest health, diet and fitness news.

I HAVE a confession to make. For most of my life, I have been sceptical about the merits of alternative and complementary medicines. But when I experienced an unpleasant condition in my 30s that couldn't be helped by conventional medicine, I ran straight to my local alternative health store.

I was seeking relief from unrelenting morning sickness. The remedies I tried – ginger supplements and wearing an acupressure wristband – had no effect. But the experience gave me a better understanding of why people with debilitating health conditions can get so desperate that they try anything.

I was reminded of this by the dispute that erupted last month when the World Health Organization (WHO) held its first global summit on traditional and complementary medicines, encompassing practices with long histories, such as Indian Ayurvedic medicine, and more recent Western inventions, such as homeopathy. The WHO is aiming to help countries integrate such therapies into their health systems.

I realise some readers may use these therapies and it really isn't my intention to criticise, not least because it would be hypocritical given my history. But the WHO's move has stirred up controversy. For instance, alternative medicine critic Edzard Ernst said on his blog that the conference was an "odd and potentially disastrous" move.

When it comes to complementary medicine, I share the views of Cancer Research UK, which has said that people have the right to use whatever remedies they choose, but they should be able to make fully informed decisions that are based on genuine evidence about the risks and benefits of any therapy.

The problem is that those who profit from complementary medicines generally haven't carried out the research to provide such evidence. It is often argued that even if there isn't evidence for benefit, most complementary and traditional medicines are generally safe, but that isn't always correct.

A case in point is Ayurvedic medicine, which is very relevant here because the WHO conference was held in Gandhinagar, India, and was co-hosted by the Indian government. Last year, India committed an estimated $250 million to help the WHO set up its Global Centre for Traditional Medicine in the country.

> **"Edzard Ernst has published reports of people who died following complementary therapies"**

Ayurveda is a collection of practices, including various dietary or exercise regimes, as well as the provision of remedies and supplements based on herbs, metallic compounds or sometimes gems.

The US National Center for Complementary and Integrative Health – generally very pro alternative medicine – says that some of the remedies and supplements can contain toxic levels of lead, mercury or arsenic.

Other kinds of complementary medicines also have potential for harm. Ernst has published a small collection of reports of people who died following complementary therapies. This included people who died from infection or from a punctured heart or liver after acupuncture, as well as people who died after chiropractic treatment, usually due to the alleged rupture of an artery in the neck during spine manipulation.

Complementary medicine can also do harm if people rely on these kinds of therapies instead of regular medicine. There are frequent reports of people dying from cancer who might have survived if they had conventional treatments, such as surgery and chemotherapy.

Complementary medicine advocates sometimes respond to these criticisms by saying "science doesn't know everything" – something I would agree with. I spend a lot of my time writing about the way that scientists, when faced with new evidence, have had to revise their beliefs about the way a drug works or whether it works at all.

Science has, however, come up with the best method we have for determining if a therapy has benefits over and above the placebo effect, known as the placebo-controlled trial – and that is what is often lacking when it comes to alternative medicines.

A WHO spokesperson told me its initiative in this area is needed because billions of people use traditional and complementary medicines, and that the WHO is committed to developing the scientific base to support the use of such therapies, to establish what works and what doesn't.

That would be welcome, but the WHO's messaging so far doesn't inspire confidence that this will be done in an appropriately impartial way.

I think we should remain open to the possibility that future trials may provide new evidence to support treatments currently classed as complementary. But until that happens, I will remain in my former position as a committed sceptic. ▮

Clare's week

What I'm reading

Our Missing Hearts *by Celeste Ng, which is more unsettling than Ng's previous novels, imagining a dystopian near-future US.*

What I'm watching

I have belatedly discovered Deadloch, *a playful crime parody that spoofs every cop show ever written, but still makes you care about whodunnit.*

What I'm working on

I'm writing about the neuroscience of free will, which is disturbing, to put it mildly.

Up next week: Chanda Prescod-Weinstein

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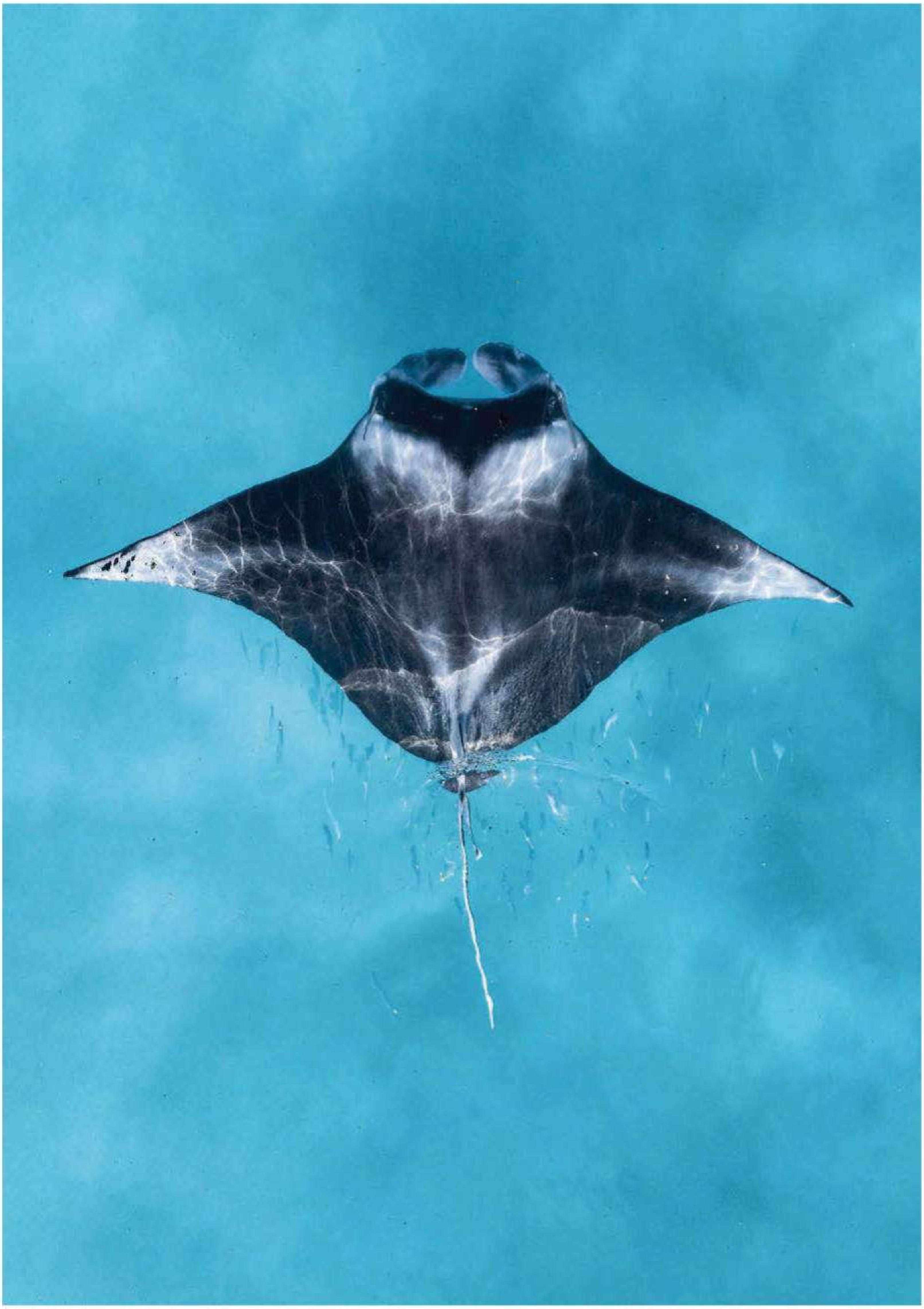

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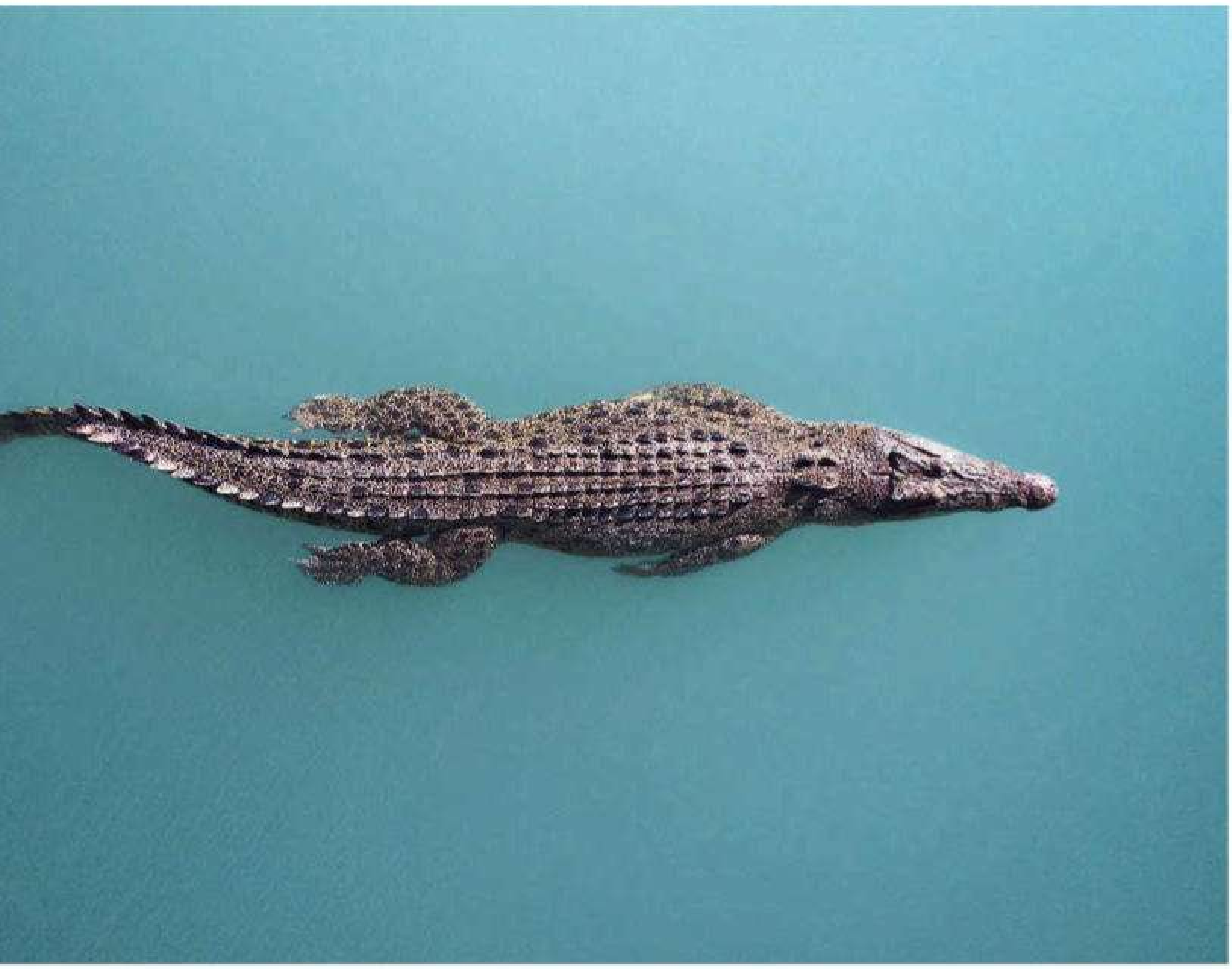

Aerial approach

Lewis Burnett,
South Australian Museum

SWIMMING serenely in seeming seclusion, beautifully framed by crystal blue waters, these shots of marine animals evoke a sense of tranquillity and power.

Capturing them from this dramatic perspective using a drone was no mean feat for photographer Lewis Burnett. He spent months tracking the creatures to create his collection "Aerial Oceans", part of which is shown here.

The shots won the Portfolio prize in the 2023 Australian Geographic Nature Photographer of the Year competition, which is produced by the South Australian Museum. Burnett hopes they will leave people feeling the "same awe of the ocean and its wild inhabitants" he feels after a day diving. "It's impossible to not feel a sense of calm after experiencing the ocean's wildlife, to not leave feeling small and insignificant in this world," he says.

A reef manta ray takes centre stage in Western Australia's Ningaloo Reef in the image at far left. With a "wingspan" that can reach 4.5 metres, this species is among the world's largest rays. Also glimpsed in Western Australia, in Willie Creek, is the unmistakable shape of a saltwater crocodile (top right). It took five months to snap the animal in blue ocean water – despite their name, saltwater crocodiles tend to be found in freshwater habitats.

Finally, below it, off the coast of Timor-Leste in South-East Asia, is a pod of Risso's dolphins. This species, with its characteristic blunt head, is usually wary around boats, so Burnett spent a huge amount of time getting close to these dolphins, he said in an announcement about his win. ▮

Gege Li

Editor's pick

On the call for less doom in climate messaging

Leader, 19 August

From John Davnall, Manchester, UK

While I accept your positive idea of easing up on doom-mongering in messages about climate change, I fear your article doesn't address one of the great climate unknowns.

You state that "climate change is happening, and we can stop it if we choose to". But we really don't know how much further the warming inertia of past emissions, coupled with feedback loops such as permafrost methane release, will take temperatures once emissions cease in a carbon-neutral world.

In particular, the oceans have been credited with ameliorating atmospheric warming by absorbing much of the heat energy of the greenhouse effect. Once carbon dioxide levels stabilise and reduce, that store of marine energy will be released. Whether that release will keep temperatures on the rise or "merely" hold them high for longer is an open question.

From Phil Elmes, Blacksmiths, New South Wales, Australia

I am pleased you are encouraging a less catastrophist approach to the messaging on climate change.

I despair to see young people frightened to the point of feeling hopeless about the future. Our message to them should be one of optimism. We will have technologies in place to reduce our influence on the rise in temperature. In the meantime, we can adapt if required. There is no need for panic, and your point on this was wise and welcome.

Global warming may spark fashion meltdown

19 August, p 30

From Hillary Shaw, Newport, Shropshire, UK

One less-discussed effect of human adaptation to rising temperatures could be a change in clothing fashions in some parts of the world, which may have wider repercussions. If we have more very hot and sunny days, will Western fashion begin to lose its appeal? Some may opt for longer, cooler dresses with arms covered, causing a change in the amount and types of fabrics produced and perhaps leading to a decline in the tattoo industry. Some parts of Western formal attire, like the suit and tie, may decline even faster, too. One benefit could be lower demand for air conditioning.

Nuclear must be at heart of the carbon-free push

19 August, p 12

From Jon Elmendorf, Houston, Texas, US

Your latest special issue on climate change was generally fair and objective, but other than a brief parenthetical reference to China's nuclear power programme, there was no recognition of nuclear power as a major and near-term contributor to reducing our carbon emissions. No "green" movement can be taken seriously without a full-throated endorsement of this.

If you win $50 billion, please use it wisely

19 August, p 21

From Robert Wright, London, UK

In "Unnatural disasters" by Friederike Otto, we learn that Multnomah county in Oregon is suing fossil fuel companies for $50 billion in damages caused by a 2021 heatwave. Thanks to Google Street View, I was able to see the nature of the place. Everywhere I looked, I saw nice houses, many with visible air conditioning and a decent car in the drive.

Those residents have obviously embraced the benefits of the industrial revolution and used their fair share of fossil fuels. If they win anything, I suggest they donate it to communities around the world who will suffer on a much larger scale from more extreme climatic changes.

Upsides of the great personal data grab

26 August, p 32

From Eric Kvaalen, Les Essarts-le-Roi, France

I agree that we need to be cautious about how we use the internet and phones because of firms trying to get our data. But I don't agree that this is "a game you can only lose", as one contributor put it. If you exercise, then your data should help you with your health insurance – and so on.

I also don't agree that the instances of "bad" use are always bad. They might expose hypocrisy or secret crimes, or provide information on dangerous people, such as those responsible for deaths and war crimes.

Still searching for the real cause of obesity epidemic

Letters, 19 August

From Jon Arch, Welwyn Garden City, Hertfordshire, UK

The fundamental problem with obesity isn't that the real cause of it has yet to be confronted, but that the real cause isn't known. If it is only that ultra-processed foods support over-consumption, as Pauline Keyne suggests, why is it that food intake in the US was stable at roughly 2200 kilocalories per day from 1999 to 2017, while obesity rates soared from about 30 per cent to 42 per cent of the population?

It is worth noting that a 2 per cent excess of energy intake above expenditure over 10 years – too small to detect – leads to about 20 kilograms of weight gain. This is enough to take a person from the typical weight category through overweight to obese.

Research suggests that body weight and composition are programmed not just by genetics, but also by early life experience, partly before birth. It is time to think more deeply.

British nuclear war movie still chills me

12 August, p 30

From Mark Edwards, Brisbane, Australia

It has been more than 35 years since I saw it, but seeing Simon Ings recommend the film *Threads* brought up memories of how horrific this fictional account of nuclear war is. It should be required viewing for all politicians in a country with a nuclear arsenal.

Sometimes, gestures can be misleading

19 August, p 34

From Sam Edge, Ringwood, Hampshire, UK

I read your piece on the power of gestures accompanying speech with interest. However, the conclusion, and especially the assertion that other people's gestures "offer a window into the thoughts that speakers have but don't express in their words", seems at odds with previous research demonstrating that people are better at detecting if others are lying if they only hear and don't see the other person.

Shedding light on a burning issue

5 August, p 12

From Nick Baker, Rowhedge, Essex, UK

The flame you used to illustrate geologic hydrogen is incandescent. It looks more like methane to me.

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Going extinct on Earth

A fast-paced story about our planet's mass extinctions will enthral readers, although **Michael Marshall** would have loved a few more new stories

Book
Extinctions
Michael J. Benton
Thames & Hudson

"DO YOU guys ever think about dying?" blurts out Stereotypical Barbie, horrifying her friends and kicking off Greta Gerwig's *Barbie* movie. Maybe she had just read Michael J. Benton's *Extinctions: How life survives, adapts and evolves*, an account of the worst calamities to have befallen life during the past billion or so years.

For a book that is essentially a catalogue of mass death, it is a remarkably breezy read. This isn't surprising, given Benton has written a string of books for general audiences. His day job, however, is as a palaeontologist at the University of Bristol in the UK, with much of his career spent studying the evolutionary history of major animal groups and the impacts of mass extinctions.

His latest book is a chronological history of those extinctions, moving from the deep past to the present. Its focus is on those that affected animals, which means it is all about the past 600 million years or so.

Earth's earlier history was dominated by microbial life, and Benton largely skips over this because we know very little about extinction events in those shadowy periods. It seems likely the rise in atmospheric oxygen and the Snowball Earth episodes, when much of the planet froze over, caused microbial die-offs, but, so far, we haven't found direct evidence in the fossil record.

Instead, Benton's story begins in the Ediacaran, the period between 635 and 539 million years ago. The Ediacaran rocks preserve the oldest evidence of animal life. Much of it is deeply strange to our eyes, such as frond-shaped organisms that look like the leaves of ferns but turn out to be animals.

As the Ediacaran transitioned into the later Cambrian, many of these organisms disappear from the fossil record. Benton calls this mass extinction "one of the most significant that Earth has seen", because it led to the origin of recognisably modern animal groups like arthropods (the group that includes insects). But there is no smoking gun – no sign of an asteroid impact, for instance – so Benton suggests that newer animal groups might have outcompeted the Ediacarans.

Moving forward in time, Benton alternates between familiar and unfamiliar stories. Many readers will know about the end-Permian extinction, in which between 90 and 95 per cent of species died out, and the end-Cretaceous extinction, in which an asteroid strike took out all the dinosaurs except birds.

For these oft-told tales, Benton reaches for novel angles.

> **"The take-home is that extinctions can also be creative events because they pave the way for new organisms"**

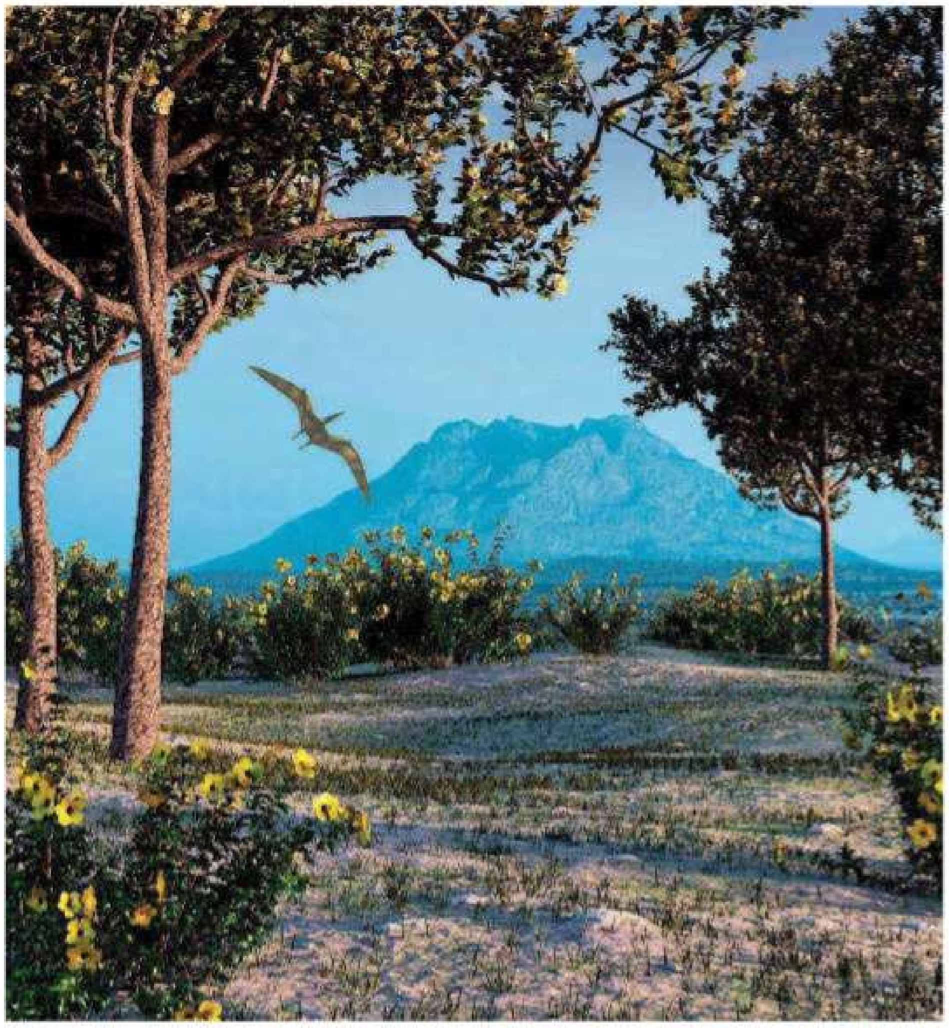
His account of the end-Permian extinction begins on the Russian steppe, where palaeontologists have identified traces of "violent rainfall, erosion, terrifying water flows and an enormous transport of rocks". For the dinosaur extinction, however, he focuses on the Tanis fossil deposit in North Dakota, which purportedly preserves animals caught in a flash flood triggered by the asteroid – in other words, animals that died on the day of the impact.

He mentions lesser-known events, too. Benton highlights the Carnian Pluvial Episode, a period of climate change that took place 232 million years ago, early in the dinosaur era. In the 1980s, geologists Mike Simms and Alastair Ruffell identified these climatic shifts and tentatively linked them to marine extinctions. At the same time, Benton, then a graduate student, found evidence of a smallish mass extinction among land-dwelling vertebrates.

It is a fascinating story of how science advances in fits and starts, with the punchline that the Carnian Pluvial Episode helped drive dinosaur evolution by clearing the decks for them.

Benton's take-home, that extinctions can also be creative events because they pave the way for new organisms, is a little well-worn. It is also only comforting from a geological perspective: as Benton makes clear, living through a mass extinction would be a slog. (Good thing we aren't causing one, eh?)

If there is a fault with this book, it is that there isn't quite enough novel material like the Carnian story for those (like me) with a strong interest in palaeontology. Nevertheless, most readers are likely to be enthralled. *Extinctions* is fast-paced, clear and doesn't skimp on the drama. If the Tanis site, with its extraordinary fossils, is news to you, there are plenty more wild tales to enjoy. ▮



The Cretaceous imagined, complete with flowers and a pterosaur

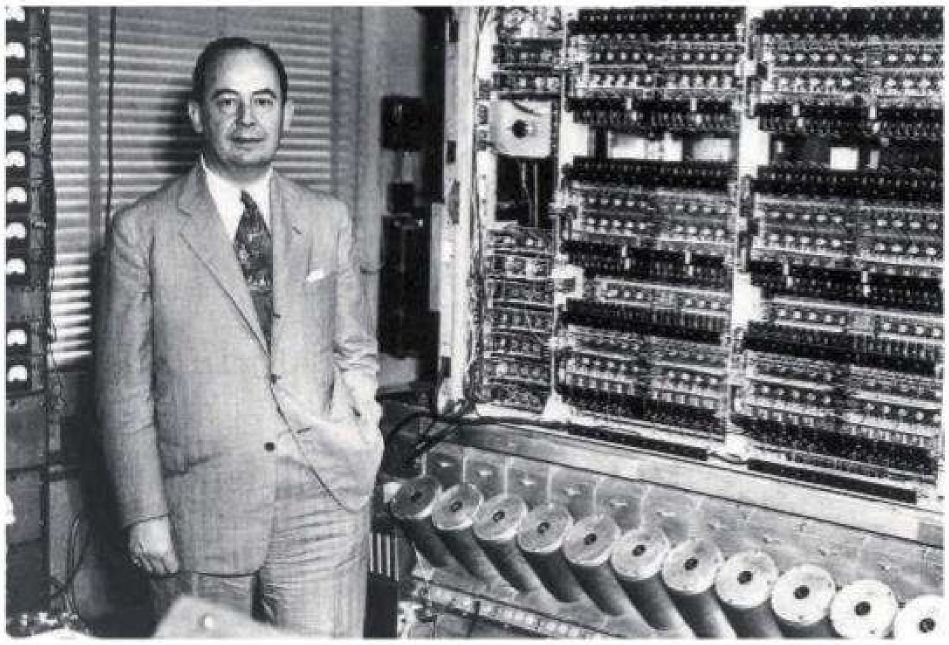
MARK GARLICK/SCIENCE PHOTO LIBRARY/ALAMY

Michael Marshall is a writer based in Devon, UK

Deconstructing a legend

The life of polymath John von Neumann is woven into a dark, strange novel by a rising literary star, finds **Alex Wilkins**

Book
The MANIAC
Benjamín Labatut
Pushkin Press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John von Neumann with MANIAC, the first computer to be based on his architecture

IT IS a curious and morbid fact that some of the 20th century's most talented scientists died by suicide or experienced mental breakdowns so severe that they had to leave their fields altogether. One often quoted physics textbook, *States of Matter* by David L. Goodstein, opens with these sentences: "Ludwig Boltzmann, who spent much of his life studying statistical mechanics, died in 1906, by his own hand. Paul Ehrenfest, carrying on the work, died similarly in 1933. Now it is our turn to study statistical mechanics."

These events are more than dark curiosities to Benjamín Labatut, whose previous book, *When We Cease to Understand the World*, was shortlisted for the International Booker prize. Instead, as he suggests in *The MANIAC* (his first book written in English), they say something meaningful about the kind of knowledge unearthed by scientists over the past century in areas such as nuclear fission, artificial intelligence and quantum mechanics – and the various ruptures this science has wrought.

***The MANIAC* centres on John von Neumann, the mathematician, physicist and polymath who contributed to or invented an improbable number of fields or devices, including game theory, the architecture of modern computers and the detonation mechanism for the first nuclear bomb.**

Von Neumann's career makes up much of the book: we read about his precocious experiments to prove the foundations of mathematics; his later years on the Manhattan Project, which produced the first nuclear weapons; and his experiments with the MANIAC computer, then the most powerful computer in the world, at the Los Alamos Scientific Laboratory in New Mexico. But it is his personal relationships that keep the book humming along: the affairs, spats and lack of interest in the moral dimensions of nuclear warfare.

We almost never hear from von Neumann himself, but instead have a portrait painted of him through short, first-person reminiscences from his family, friends and rivals. Many of these "recollections" are fictionalised, but Labatut says they are based on real events and quotes. This strange, fabulistic mixture of fact and fiction can be disorienting, but it also helps weave a compelling, immersive narrative.

Though von Neumann's scientific contributions were inspired and singular, Labatut also sees them as part of a greater movement: the steady abstraction of the world, and life, into numbers and equations.

Ehrenfest's encounters with quantum mechanics, and its fundamental unknowability, are the starting point of *The MANIAC*. Its ending – or perhaps the beginning of the end for us puny humans – focuses on AI firm DeepMind's 2016 duel with Lee Sedol, then the world's best player of Go, an ancient and fiendishly complex board game. For Labatut, this marks the apparent dawn of the age of AI. Von Neumann's obsessions with artificial life and cellular automata may have started this work, he suggests, but the story seems to be just beginning.

Of course, viewed from a modern perspective, many of Ehrenfest's mental health crises might as easily be explained by a lack of adequate healthcare, while von Neumann's "idiosyncrasies" may fit the cultural norms of their time. Labatut's infusion of the esoteric and profound, as well as his fabulations, into what many scientists see as the plain facts of reality may not work for all. But he is a writer first, with no formal scientific training: he isn't interested in plain facts, rather the emotional and philosophical landscape they conjure.

Science has too often failed to look past its own backyard or to examine its moral responsibilities. This myopia comes with grave consequences, and *The MANIAC* is in deadly earnest when it warns that they shouldn't be ignored. ▮

New Scientist recommends

Catherine de Lange
Magazine editor
London

As I eagerly await *New Scientist*'s next book club pick, I've been reading a book that has languished on my shelves for years. I wish it hadn't. **The Man Who Couldn't Stop**, by science journalist David Adam, is an account of living with obsessive compulsive disorder. For him, and many others in the 1980s and 90s, it presented as an intense fear of getting AIDS. Adam navigates the topic so skilfully you never feel you're getting to the "science bit".

I've also been gripped by **The Retrievals**, a podcast about a fertility clinic where women had their eggs extracted without painkillers, after a nurse swapped fentanyl for saline. The series looks at perpetrator psychology, but it's really about the shocking way the women's excruciating pain was dismissed.

On a lighter note, I took my family to the **National Railway Museum** in York, UK (pictured). What a treat! My children went wild, but we missed the opening of an interactive gallery, so we'll just have to return.

THE BOARD OF TRUSTEES OF THE SCIENCE MUSEUM

The film column

Be very afraid What happened when international criminals attempted to steal $1 billion from Bangladesh Bank? *Billion Dollar Heist* tells a true story that could be a terrifying rehearsal for all-out cyberwar, says **Simon Ings**

Simon Ings is a novelist and science writer. Follow him on Instagram @simon_ings

Film

Billion Dollar Heist

Daniel Gordon

Available to stream

Simon also recommends...

Book

The Shockwave Rider

John Brunner

The progenitor of all cyberpunk finds Nick Haflinger, science fiction's first fully realised computer hacker, fracturing under the pressures of bureaucracy and surveillance.

Film

Mission Impossible – Dead Reckoning Part One

Christopher McQuarrie

On general release

The latest in this too-daft-to-resist thriller series sees Tom Cruise facing off against a self-learning, truth-eating digital parasite.

UNIVERSAL PICTURES

Storybook graphics and leading experts create a chilling docudrama

ON 4 February 2016, after a year of using malware to scrutinise the computer systems of Bangladesh Bank, the country's central bank, an international criminal group tried to steal $1 billion from it. The bank was a soft target, with no firewall and simple $10 electronic switches connecting it to the SWIFT global payment system used by more than 11,000 financial institutions globally.

The Federal Reserve Bank of New York is the largest in the world, housed in one of the most secure buildings, with its own power plant, water supply and communications. But in 2016, it hadn't thought to put in a hotline for its customers in case they had any emergencies. In an institution responsible for providing financial services to foreign central banks, international organisations and the US government, this proved to be, shall we say, embarrassing.

What happened next is told in *Billion Dollar Heist*, a documentary that makes up for what it lacks in expensive locations with excellent comic-book graphics and terrific experts. An interview with investigative journalist Misha Glenny provides the narrative, while Reuters journalist Krishna Das guides us through the heist.

The criminals were trying to remove funds from an account held by Bangladesh Bank at the Federal Reserve Bank. Of the 35 financial transactions they attempted, the Federal Reserve Bank cleared five. This sent $101 million in two directions: $20 million to Sri Lanka (a spelling error raised a red flag, halting the transaction) and $81 million to the Philippines, where national banking laws meant the stolen funds couldn't be frozen until a criminal case was lodged.

> “State-sponsored cybercriminals ride a boom created by increasingly effective global sanctions”

Most of the $81 million disappeared into the country's casino industry (exempt from anti-money laundering laws) and is now presumably lost forever.

Requests for payment continued to pour in, totalling around $1 billion. By then, more by luck than good management, the fraud had been detected by Bangladesh Bank (not the hack, which took months to unpick).

Computer security expert Mikko Hyppönen and Eric Chien, technical director of software firm Symantec's security technology and response division, explain the implications as the story unfolds.

It turns out that the Lazarus Group, bankrolled by the North Korean government, was to blame. In 2017, it went on to attack five Asian cryptocurrency exchanges and steal $571 million. Lazarus is one of 13 or so state-sponsored hacking groups, including APT 10 in China and Sandworm in Russia. If the cybercriminals just worked to get rich, that would be bad enough, but they are for hire, riding a boom created, we learn, by increasingly effective global sanctions. So, if the daylight world of diplomacy stops your bank accounts, you know who to call.

Billion Dollar Heist is directed by Daniel Gordon, whose *The Game of Their Lives* about the 1966 North Korea football team drew him into political territory. Here, he tells a complex story clearly. This is a caper movie, albeit with a big sting in the tale, preparing us for the world such heists are ushering in.

We are now awaiting an all-out cyberwar, due to Lazarus and other groups that the US state department has designated “advanced persistent threats”. Everything from health services to transport, comms, finance and the apparatus of state are just one human error away from compromise, and annihilation. ▮

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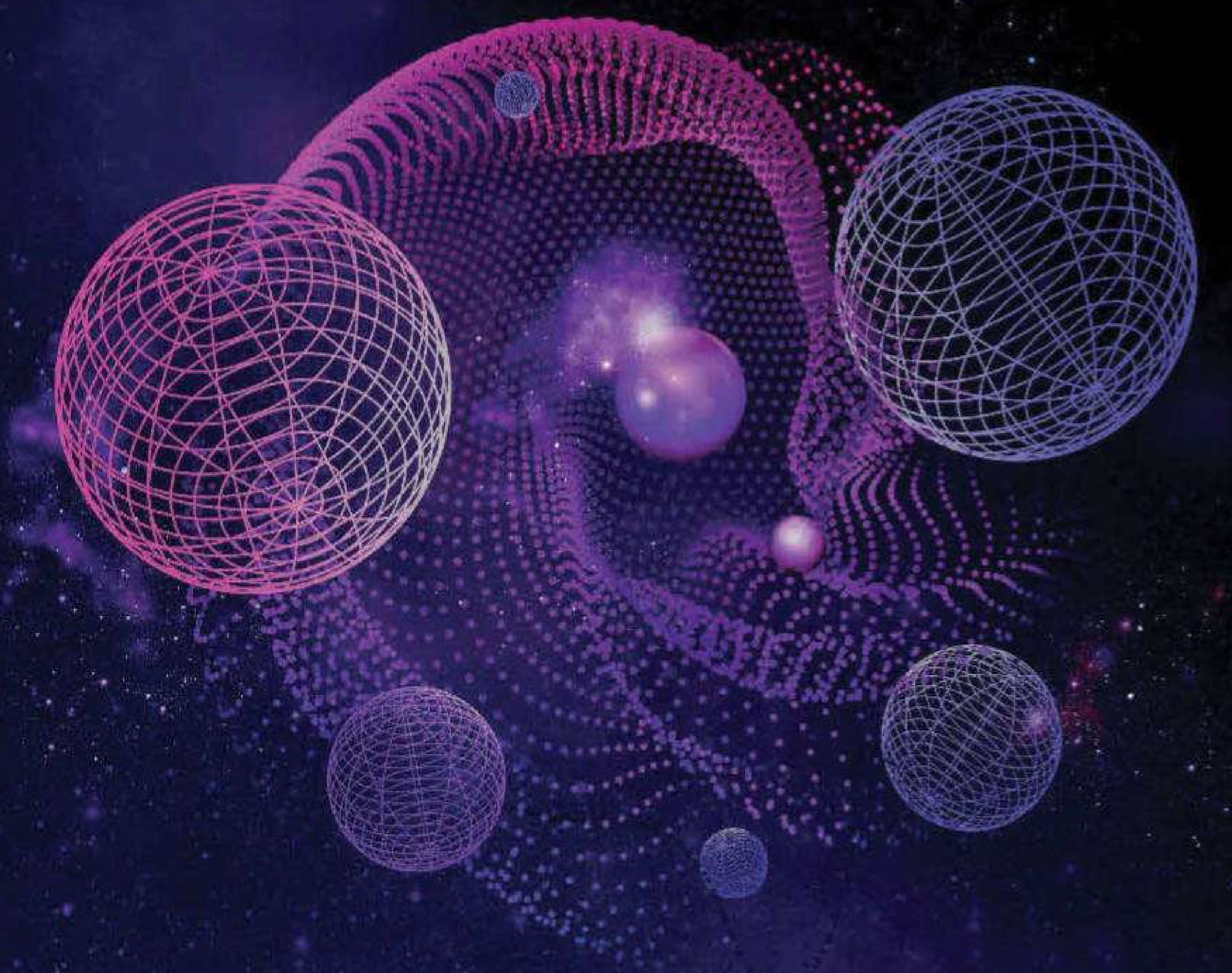

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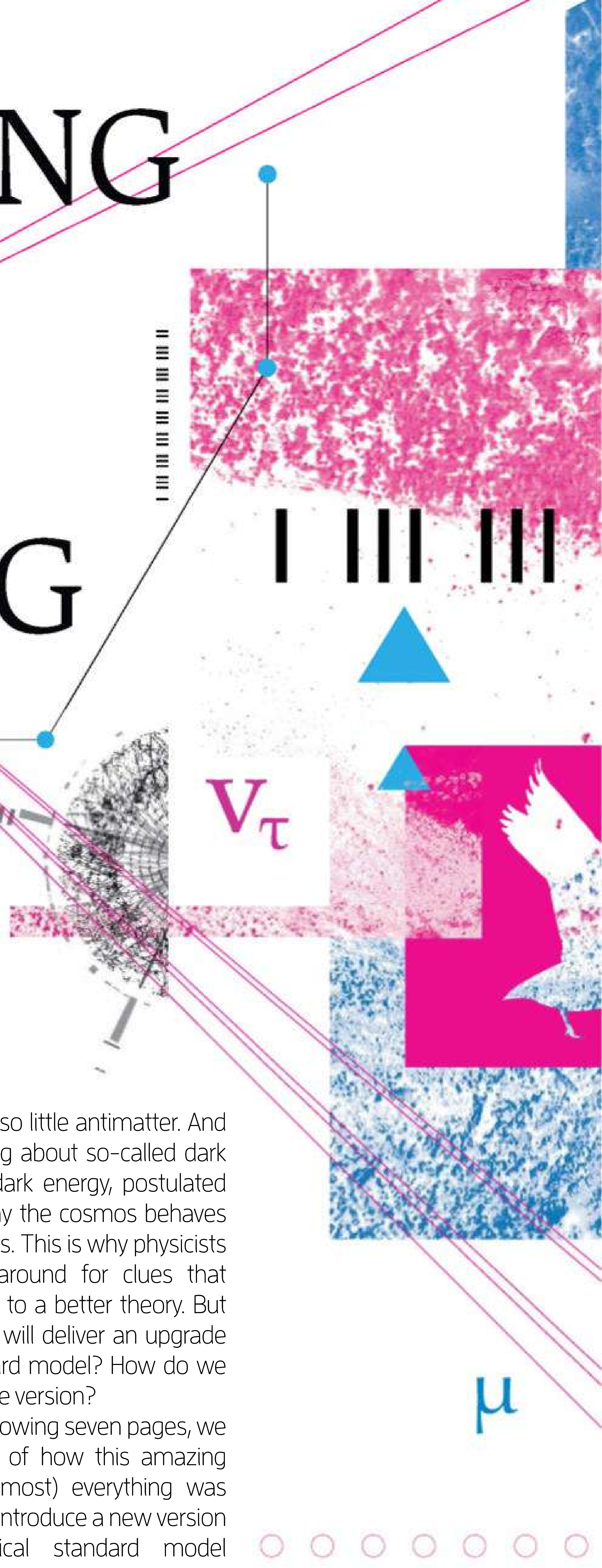
THE AMAZING THEORY OF (ALMOST) EVERYTHING



IN 1973, physicist Steven Weinberg gave a talk in Aix-en-Provence, France. It was there, according to Weinberg, that he first used the term "standard model" to describe the nascent description of the fundamental constituents of the universe and their interactions. Fifty years on, the standard model of particle physics is a stunningly accurate picture of what everything is made of and how it all works to produce reality.

Practically everything, anyway. Because although the 50th anniversary is well worth celebrating, it is impossible to ignore the fact that the theory is incomplete. It doesn't explain gravity, or why we have so much matter in the universe and so little antimatter. And it says nothing about so-called dark matter and dark energy, postulated to explain why the cosmos behaves in certain ways. This is why physicists are casting around for clues that could lead us to a better theory. But which, if any, will deliver an upgrade to the standard model? How do we find the deluxe version?

Over the following seven pages, we tell the story of how this amazing theory of (almost) everything was put together, introduce a new version of the typical standard model visualisation and let six of today's leading physicists explain how they think we will finally discover a more complete picture of reality.

How we built the standard model

The finest theory in physics was gradually assembled over many decades by scientists across the world

LOOK closely enough and almost everything we know of in the universe boils down to a handful of elementary particles. These entities constitute individual threads of the scientific masterpiece that is the standard model of particle physics, our current best picture of matter and its workings.

Its roots lay in the quantum revolution early in the 20th century, where the classical, common-sense notion that everything is predictable was unceremoniously thrown out. By contrast, the development of the standard model was anything but a revolution. Instead, it was more like the gradual forming of a new order, constructed piece by piece by dozens of physicists across decades.

Many expected the new order to fail. But it didn't. In fact, the standard model has survived every test we have thrown at it, including attempts to create new particles or to find new forces that it doesn't predict (see "How to break the standard model", page 36). So how, exactly, did physicists working throughout the 20th century come up with such an unbreakable framework? This is the story of the most successful theory we have ever devised.

Life was simpler in the 1920s. As far as anyone knew, the only elementary particles were photons, which made up light; protons, found in the centres of atoms; and electrons, which orbited around atomic nuclei. It was a simple picture, but a troublingly immutable one.

According to quantum physics, which arose in that decade, there was no way for these particles to be created or destroyed. Yet, for example, when you shine a torch, electrons in the torch seemingly create and spew out photons. It was mathematician Paul Dirac who realised that the potential for light exists everywhere, in the form of an underlying field. This field is so weak as to be invisible, but given the right energy – if it interacts with an electron, say – it will develop a spike, or excitation, which we observe as a photon.

Dirac called this theory quantum electrodynamics (QED). It was the first quantum field theory – one in which invisible fields, not particles, are the ultimate fundamental entities. Such theories would come to be the bread and butter of particle physics; the standard model itself is merely a more elaborate one. Successful as they have been, however, they are hard to stomach. When a field isn't excited into particles proper, it is frustratingly unobservable – a background murmuring of not-quite-somethings that physicists have come to call "virtual particles".

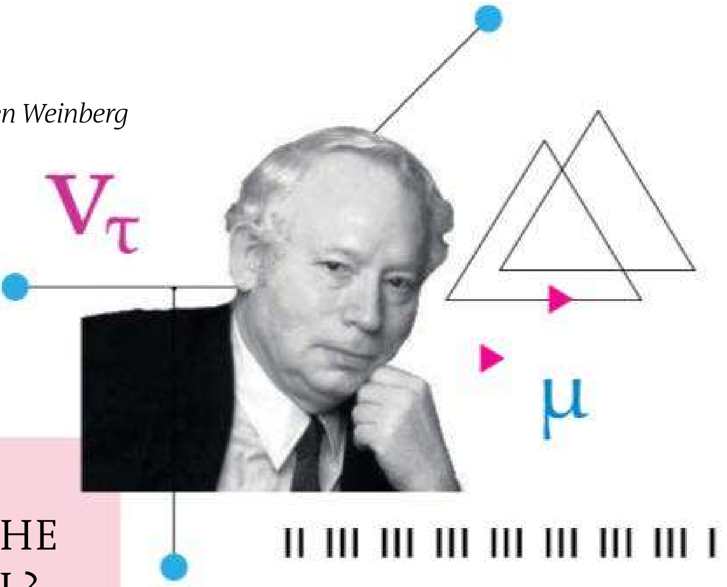
Within a few years of Dirac's QED, other theorists had extended the field concept to electrons and protons. This allowed physicist Enrico Fermi to explain how radioactive materials can emit electrons when their atomic nuclei don't actually contain any. The unchanging picture of subatomic matter was gone. Building on work by theorist Wolfgang Pauli, Fermi showed that electrons could be created, so long as sprightly, neutral particles called neutrinos are created simultaneously. The journal *Nature* rejected Fermi's paper on this, saying "it contained speculations too remote from reality to be of interest". Yet the neutrino, experimentally discovered in the 1950s, was only one of many strange new particles that physicists would have to come to terms with.

THE first addition, courtesy of British experimentalist James Chadwick in 1932, was the neutron, a neutral particle around the mass of the proton. Across the Atlantic, a young US physicist called Carl Anderson had spotted some backwards-looking tracks in photographs of electron ionisations. These turned out to be something Dirac had predicted: examples of the first antimatter particle.

At this point, the world of particle physics still just about made sense. There were atoms, made of protons, neutrons and electrons; there was light, or photons; and there were positrons, or antimatter. But in 1936, in partnership with his colleague Seth Neddermeyer, Anderson found something no one expected: a seemingly heavier version of the electron called the muon.

This unexpected muon was the least of theorists' worries, though. A few years earlier, J. Robert Oppenheimer, an intense, straight-shooting physicist, had unearthed a rather large problem with QED. He realised there were infinitely many ways an electron could emit and reabsorb virtual photons – meaning its energy ought to be infinite, which made no sense. Soon, the infinities were cropping up everywhere. The theory was "in a hell of a way", said ›

Steven Weinberg



“A model of leptons”

TOP: LARRY MURPHY/THE UNIVERSITY OF TEXAS AT AUSTIN

Oppenheimer. The arrival of the second world war didn’t help matters.

When that conflict was over, three different methods to constrain the infinities came to light: two in the US, devised by Julian Schwinger and Richard Feynman, and one in Japan, conceived by Sin-Itiro Tomonaga. In the end, mathematician Freeman Dyson realised they all amounted to the same thing. “It came bursting into my consciousness, like an explosion,” he later recalled.

DYSON’S singular method was called renormalisation. It works by ignoring the lion’s share of the electron’s energy, which isn’t measurable in an experiment. Only calculate what can be measured and the total energy is no longer infinite. It was a ridiculously simple idea, but it worked for a time.

By the 1950s, two other forces of nature beyond the electromagnetic force at the heart of QED were coming under increasing scrutiny: the weak force, which is behind Fermi’s radioactive decay and neutrinos, and the strong force, which holds protons and neutrons together in atomic nuclei. For these forces, renormalisation just didn’t work.

This time, the crucial insight came from Chen-Ning “Frank” Yang, a mild-mannered Chinese theorist who had relocated to the US. He had been dwelling on symmetries in particle interactions, a property that implies certain values are preserved during a transformation of some sort (see “Upside down, back to front”, right). For instance, when photons interact with electrons, the equations naturally balance without needing the electron charge to vary. In this sense, the raison d’être of photons is to conserve the electron charge. We call this charge symmetry.

Working with his colleague Robert Mills, Yang introduced the idea that force-carrying particles similar to photons must exist in order to conserve other particle qualities. The trouble was, he couldn’t make any definite predictions – much to the annoyance of Pauli, who heckled Yang so much during a presentation that the latter fell silent and nervously sat down. Oppenheimer, chairing the seminar, came to his defence, declaring “we should let Frank proceed”. It was a good job they did. By showing how the concept of symmetry in QED (a renormalisable theory) can, in principle, be applied elsewhere, Yang had laid the groundwork for a new class of theories that would form the backbone of the standard model.

IN THE 1960s, Steven Weinberg, together with fellow physicists Sheldon Glashow and Abdus Salam, created a renormalisable field theory that encompassed both QED and the weak force. It predicted that certain qualities of neutrinos are set by three new particles, known as the W+, W- and Z bosons. These are what we call carriers of the weak force.

Meanwhile, physicists including Murray Gell-Mann were fashioning a new theory of the strong force that holds protons and neutrons together in atomic nuclei. This theory, known as quantum chromodynamics, showed that protons and neutrons are made up of smaller entities known as quarks, the qualities of which are set by yet more new particles called gluons, the carrier particles of the strong force.

By now, with particle colliders becoming a standard tool for discovery, the list of particles being found was rapidly proliferating. Most of these were composite, formed of quarks in different combinations. Although quarks in protons and neutrons come in either “up” or “down” flavours, more flavours were needed to account for the diversity of other composites.

PHYSICISTS eventually settled on there being six quarks across three generations of elementary matter particles. In the first generation were the up and down quarks, along with the electron and the electron’s associated neutrino. The second and third-generation particles appeared to be progressively heavier copies of the first. ›

> *“If I could remember the names of all these particles, I would have been a botanist”*

WHO INVENTED THE STANDARD MODEL?

There was no single moment when the standard model came into being, so the date for its anniversary is up for debate. A meeting in 2018 celebrating 50 years of the standard model took its genesis as physicist Steven Weinberg’s 1967 paper “A model of leptons”. The term was introduced in scientific literature in 1975, where it was mentioned in passing, suggesting it was already in circulation.

Weinberg said he first used the term at a talk in 1973 in Aix-en-Provence, France. But even he expressed doubts about its origin. “I think I’m the one who gave it that name,” he said in 2010, before swiftly adding: “I’ve never been quite sure about that.”

UPSIDE DOWN, BACK TO FRONT

The standard model was guided by a principle shown by mathematician Emmy Noether in 1918: that every symmetry implies a conservation law. The symmetry of physics in time implies energy is conserved, for instance, and symmetry in space implies momentum is conserved.

This proved indispensable to early particle physicists (see main story) who spotted plenty of new symmetries. From these, they inferred conservation laws that revealed which interactions were possible. A symmetry in the behaviour of electrons and neutrinos, for instance, led to electromagnetism and the weak nuclear force coming together into electroweak theory.

Taking symmetry much further, we get “supersymmetry”, an extension to the standard model that says every particle has a heavier superpartner. So far, there is no evidence for this.

THE STANDARD MODEL REIMAGINED

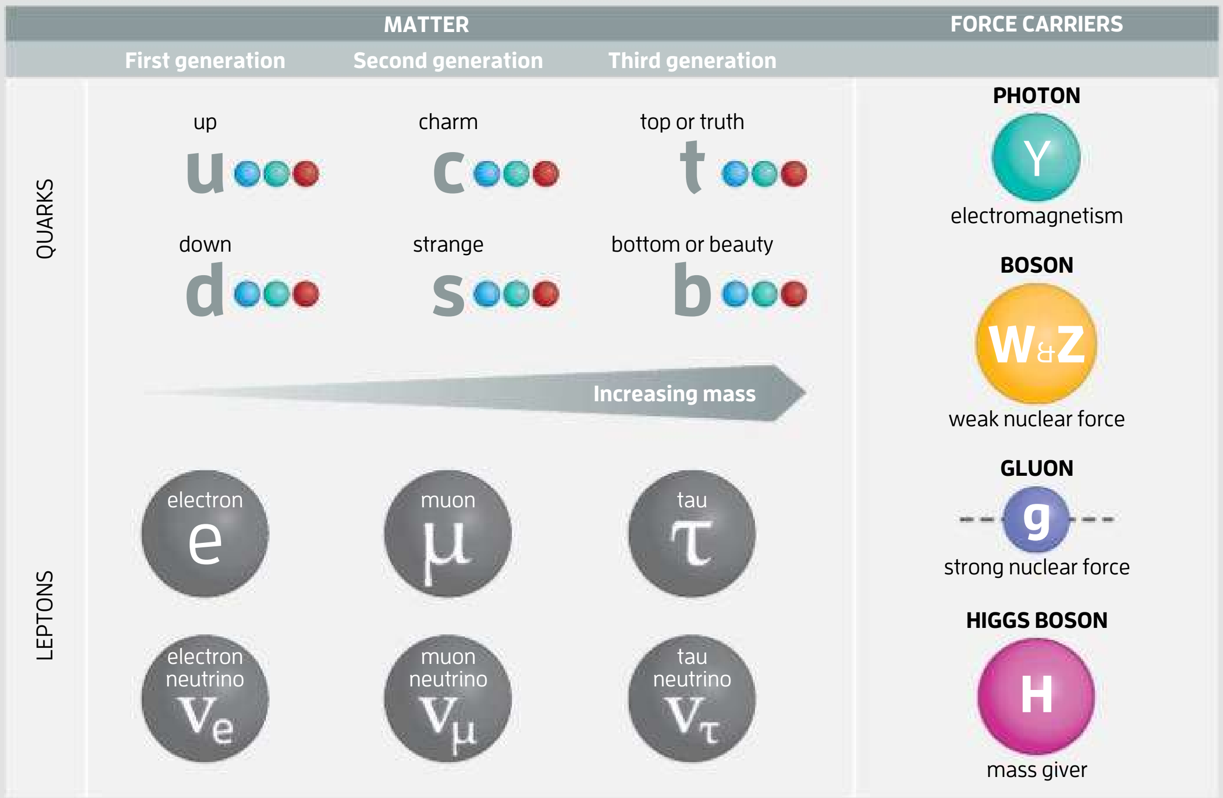
The standard model of particle physics is often illustrated as a simple grid showing the 17 basic particles (right). But an alternative way of visualising it reveals the complex rules that govern how the particles and forces interact.

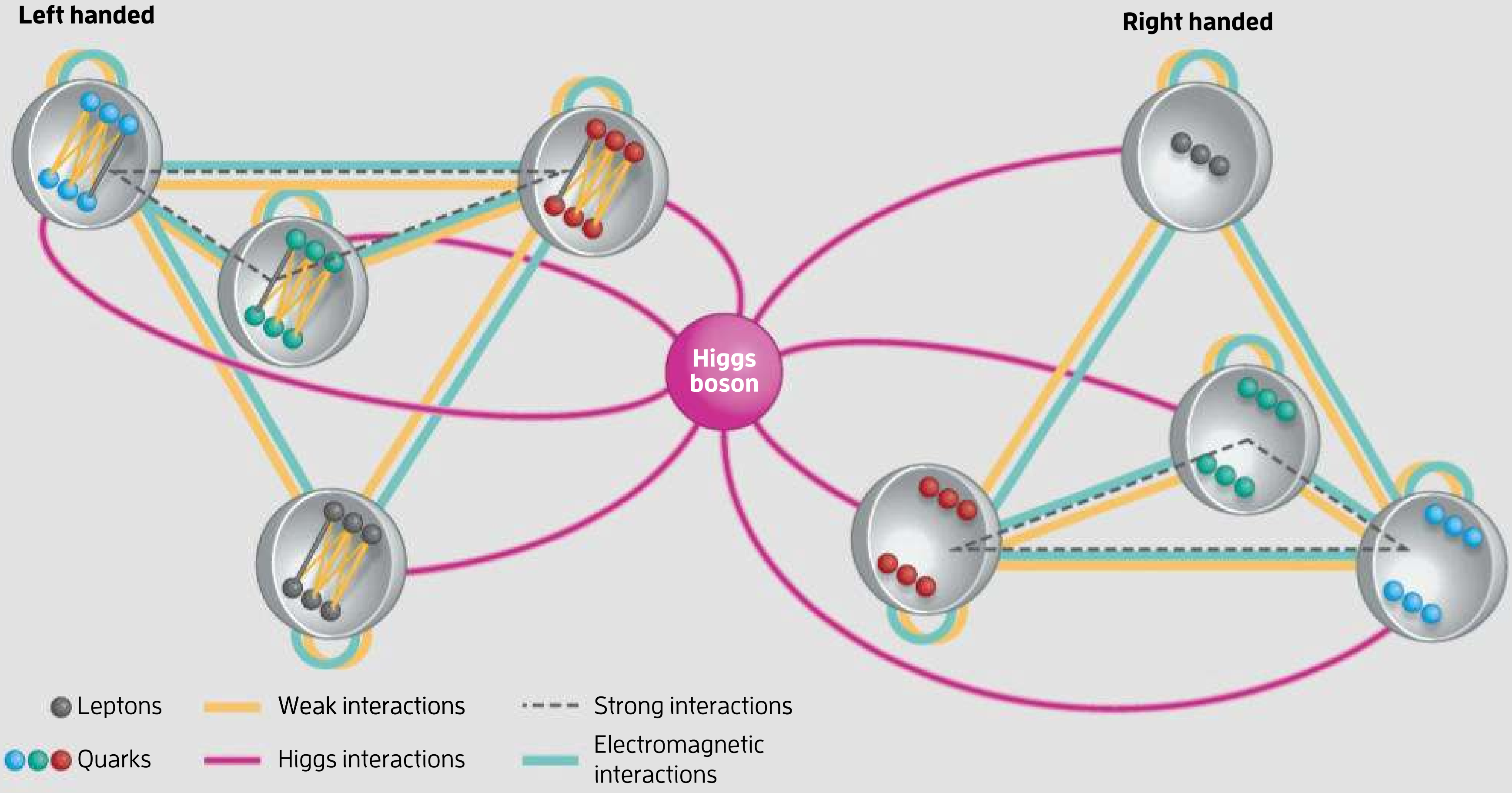
The conventional grid shows three generations of quarks (which feel the strong force) and leptons (which don't). Then there are the bosons that mediate three of the fundamental forces of nature – the strong and weak nuclear forces and electromagnetism. But it doesn't give us the full picture.

For one, there are parts missing, like the fact that most particles can occur in two forms of a property called handedness: right-handed and left-handed. It also tells us nothing about which particles feel which forces. There are mysteries it glosses over, too, like the fact there are no right-handed neutrinos, at least that we know of. "The standard grid, as lovely as it is, looks finished," says Chris Quigg, a theoretical physicist at the Fermi National Accelerator Laboratory in Illinois. "But the standard model is not finished."

Quigg thought we needed a new way to visualise the theory that reflected its messiness. In 2005, he came up with his answer: the double simplex (below). Made of two pyramids, linked by the Higgs boson, one half represents left-handed particles and the other right-handed ones. Each pyramid vertex groups generations of related particles together.

By using lines of different colours, the double simplex shows how particles interact through different forces. The lack of right-handed neutrinos is shown by the smaller number of particles in the right-handed pyramid. Here, too, you can see there are no weak interactions inside each shell, meaning that right-handed quarks and leptons can't switch between different flavours or generations (see main story). "The difference between left-handed and right-handed particles is one of the big mysteries of the standard model," says Quigg. In the usual grid, these complexities are hidden, but the double simplex celebrates them.





To this day, no one knows why, when it comes to elementary particles, nature is so profligate. "If I could remember the names of all these particles," said Fermi, "I would have been a botanist." There was just one more to complete the set: the Higgs boson, the particle that fixes the mass of all others. Hypothesised back in 1964 by theorist Peter Higgs, among others, it was only in the early 1970s that it came to be taken seriously. It was discovered another 40 years after that. "It is nice to be right about something sometimes," said Higgs after it was found in 2012.

With the theorised Higgs admitted to the stable, Weinberg delivered his 1973 talk introducing the name for the collection of entities that govern the most fundamental aspects of reality: the standard model of particle physics. The various patches of research had been stitched into a complete account of all the elementary particles, which, to this day, has never been contradicted by any experimental data. "The theory we now have is an integral work of art," Glashow wrote a few years later, "the patchwork quilt has become a tapestry."
Jon Cartwright

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How to break the standard model

Six leading researchers describe what they believe are the most promising routes to new physics

Collisions at the energy frontier

Jon Butterworth
University College London

IT IS always risky to bet against the standard model of particle physics. Historically, most people who have done so have lost. But over the next decade and a half, the Large Hadron Collider (LHC) will continue smashing protons together and examining the messy aftermath. And it is there, within the details of these collisions, that I will be looking most closely for evidence of new physics beyond the standard model.

I work on what we call the "energy frontier", where concentrating a lot of energy into colliding subatomic particles can give us access to new physics. This works in two related ways. Firstly, if there is a new, heavy particle out there, then we might be able to make it if we have enough energy. Secondly, the highest-energy colliders are, in a sense, the highest-resolution microscopes. As we get to higher energies, the resolution with which we can probe the structure of matter increases.

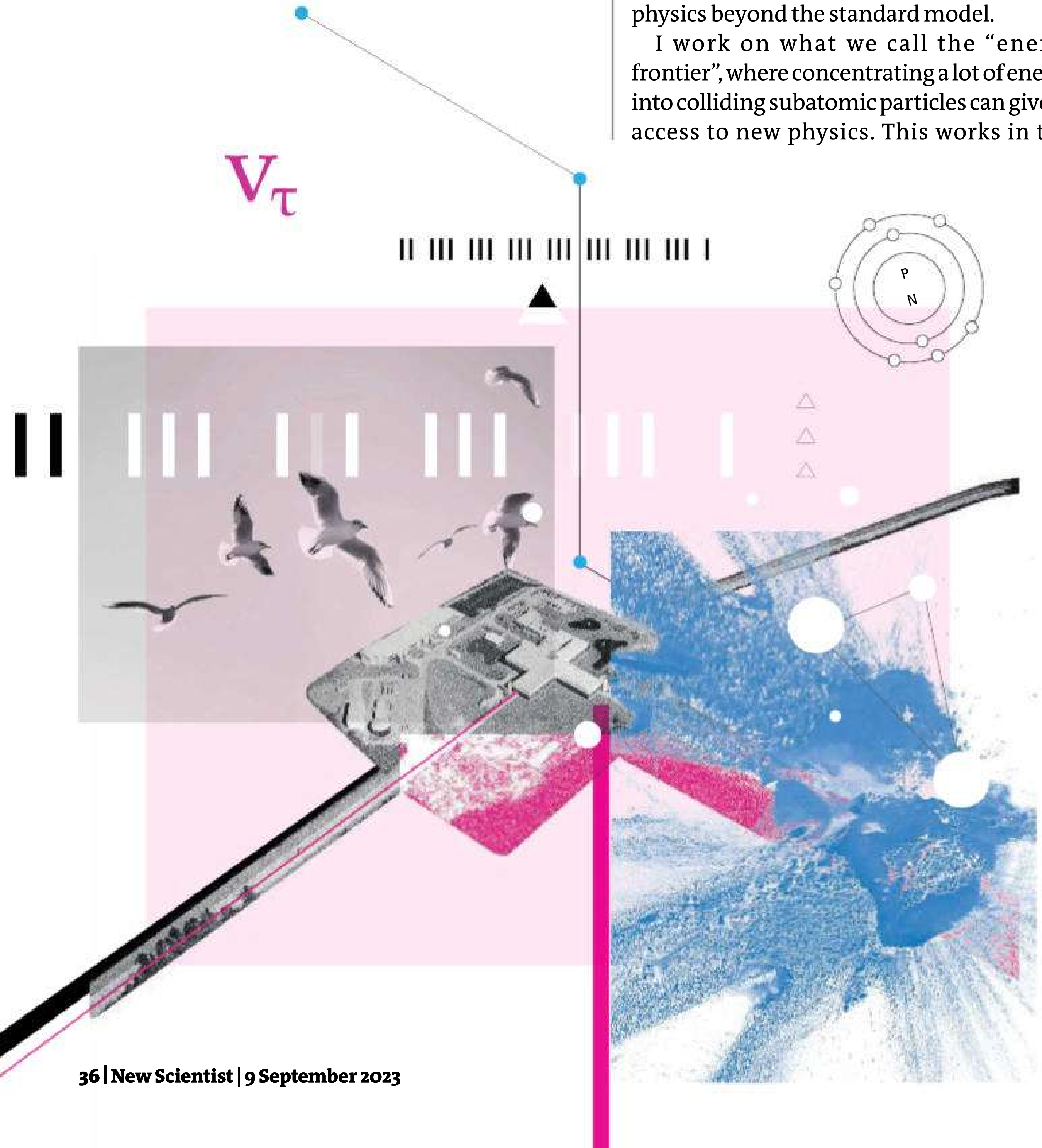
We have pretty much maxed out on the energy we can get to, but we still plan to record around 10 billion more collisions. And more is better. Determining whether we have some physics beyond the standard model is like trying to determine whether a dice is fair or not. Six rolls of the dice will tell you next to nothing, but 6 million will give you a good idea.

A plethora of different things can happen when we collide protons at the LHC. Multiple Higgs bosons, W and Z bosons, very high-energy photons and jets of hadrons arising from scattered quarks and gluons can all be produced. So far, we know the distribution of these is about that expected of the standard model. But in some cases, that is a very approximate "about".

Some important types of collision – for example, the production of pairs of Higgs bosons – indicated by the standard model are so rare that they haven't yet been seen. Many ideas for physics beyond the standard model make predictions for things that could easily hide under that "about". Over the next several years, we will make measurements that could, and I hope will, flush them out.

This effort requires a couple of things to happen. We experimentalists need to make more measurements to quantify how well the standard model is really doing, and they must be as independent of the theory as possible. We can't avoid making theoretical assumptions sometimes, we just have to minimise their impact.

On the theory side, the predictions need to increase in precision. We don't directly measure the Higgs mass, for example, but infer it from particles produced in a collision. Making more precise predictions, which can be compared directly against experiments,



means we can make better inferences about the underlying processes.

Both of these are already happening. I look forward in the next few years to heated exchanges about the level of agreement, or disagreement, between theory and experiment along the lines of recent discussions about the anomalous "magnetic moment" of the muon (see "Muons behaving oddly", page 38), for example.

Even if everything we measure agrees with the standard model, that will still be important. It will mean we have established that physics beyond the standard model lies far above the Higgs mass and hence the capabilities of current particle colliders. That may not help us much in understanding dark matter or other questions the standard model leaves unanswered. But we don't get to choose nature, all we can do is explore it to the best of our ability.

Hunting cosmological chameleons

Clare Burrage

University of Nottingham, UK

THE standard model fails to account for 95 per cent of the contents of the universe. Cosmologists split this unknown portion of the cosmos into 27 per cent dark matter, which clumps together under gravity, and 68 per cent dark energy, which causes the expansion of the universe to accelerate. We have a plethora of theories for what dark matter could be. Dark energy, on the other hand, remains more mysterious. I have chosen to look for a new force, carried by a new particle, that could explain dark energy.

We expect particles associated with the acceleration of the expansion of the universe to have two properties. Firstly, they should be very light, and secondly, they should mediate a "fifth" force – beyond those of gravity, electromagnetism and the strong and weak forces – across cosmological distances. Many precise experiments have looked for light particles and long-range fifth forces without seeing them.

Over the past few decades, however, we have realised the environment might affect the behaviour of a fifth force. In particular, if a particle that transmits the fifth force can change its mass as the density of its environment changes, the force can only act over short distances in dense regions, but over long ranges in less dense ones.

The ability to change their properties to evade detection has earned these proposed particles the name "chameleons". This doesn't mean they are impossible to detect, we just have to carefully design our experiments.

Some objects can be so small that the chameleon doesn't have enough room inside it to change its mass, so the behaviour of the force also doesn't change. Because of this, if we drop a tennis ball and an atom side by side, we would expect the atom to fall faster than the ball if this fifth force exists.

Dropping individual atoms is hard to do, but, with new experimental techniques, we can measure how atoms fall extremely precisely. We cool clouds of atoms to make them as still as possible. Then, we shine a laser at them to excite an electron orbiting the nucleus of an atom from one energy level to another. When this atom absorbs a photon from the laser beam, an electron is excited, but the atom also starts moving.

At this point, it is possible for the atom to be in a superposition of two states at the same time, one in which it absorbed the photon and is moving, and the other where it didn't and isn't. By pulsing the laser, we can spatially separate these two states and then recombine them. In between the pulses, the atoms fall freely under the influence of gravity and the hypothetical fifth force. We try to detect if the dark energy force is causing atoms to fall faster than we would expect.

So far, experiments haven't seen any evidence of new forces, constraining our models. Within the next few years, I hope we will detect chameleon particles or rule out this model altogether. Either way, we will be closer to understanding a mysterious chunk of the universe that can't be described by the standard model.

> *"Particle colliders aren't the right tools to search for a specific kind of new physics"*

SHUTTERSTOCK/TRAVELARIUM.PH

Quantum sensors

Surjeet Rajendran

Johns Hopkins University, Maryland

PARTICLE colliders have had a revolutionary impact on our understanding of the universe, but these wonderful machines aren't the right tool to search for a specific kind of new physics: particles that interact weakly with the electrons or protons being smashed together.

Finding these so-called weakly coupled particles is an important avenue to explore, since much of our observational evidence for physics beyond the standard model is "dark" physics – relating to dark matter and dark energy. This "darkness" means they don't interact much with the electrons, protons, neutrons and photons we use in experiments.

To detect weakly interacting particles, not only do sensors need to measure minuscule effects, but they must also be immune to noise. The art of creating technologies that solve these problems is called precision sensing. Explosive developments in this field over the past two decades have led to astonishingly accurate sensors by exploiting the wonders of quantum mechanics.

To create an accurate sensor, we need a near-perfect yardstick to use for the measurements. Consider the amazing fact that there are 10^{80} hydrogen atoms in the observable universe and every one is identical. A quantum sensor exploits this fact to create robust yardsticks that enable high-precision sensing.

An example is the use of synchronised atomic clocks, which "tick" based on the behaviour of electrons within certain atoms, to search for dark matter. ›

A grand scientific success of precision sensing is the LIGO experiment. This uses devices called interferometers to search for gravitational waves, ripples in space-time. Interferometers contain waves, usually of light, which interfere to create patterns that can be studied to reveal forces or fields that have moved through the device. The discoveries of gravitational waves by the LIGO collaboration could be a harbinger of the kind of physics we may go on to discover using other quantum sensors.

Physics is an experimental science, so we aren't going to know what is there without experimental exploration. This is a frustrating fact for the theorist who might want to discover the theory of everything from their armchair. But, sobering as this is, I see it as a call to action: there is new physics out there and our job is to find it.

Rethinking time

Emily Adlam

Chapman University, California

WE TEND to assume that time works in a linear way. Even the standard model is traditional when it comes to how we think of time: some "input" evolves into an "output". Yet many other parts of modern physics, such as Albert Einstein's equations of general relativity, aren't a good fit with this simple time-evolution picture. This is why I believe that, to find physics beyond the standard model, we should move away from the time-evolution paradigm.

> *"In a couple of years, we could irrefutably confirm there is physics beyond the standard model"*

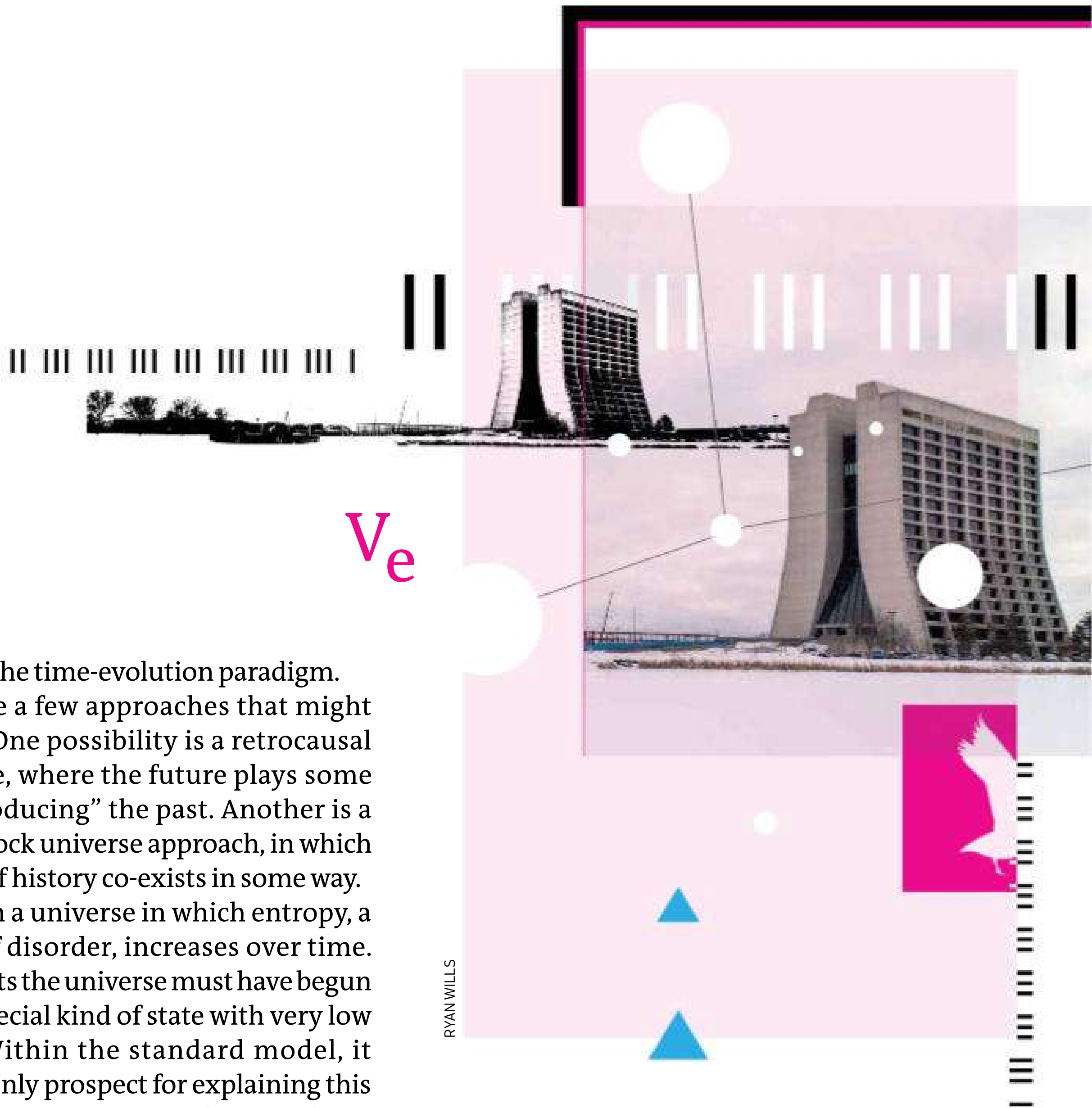
There are a few approaches that might replace it. One possibility is a retrocausal perspective, where the future plays some role in "producing" the past. Another is a so-called block universe approach, in which the whole of history co-exists in some way.

We live in a universe in which entropy, a measure of disorder, increases over time. This suggests the universe must have begun in a very special kind of state with very low entropy. Within the standard model, it seems the only prospect for explaining this is to imagine a process producing a large number of possible universes, or multiverses. Since we find ourselves in this universe, the argument goes, we must be in one of the universes with a low-entropy initial state. But if we don't start from a time-evolution picture, there may be a way to explain the special initial state without imagining other universes.

The block universe approach also seems like a promising route to one of the largest problems that the standard model can't solve – unifying gravity and quantum mechanics – since our best theory of gravity, general relativity, seems most at home in a block universe picture.

Excitingly, we may soon have new experimental data. Recently, there have been proposals for experiments testing, for example, whether space-time can enter superpositions. One experiment involves putting two masses into quantum superpositions where they are effectively in two different positions at once, then seeing if it results in quantum entanglement. If entanglement is created in that experiment, this probably indicates that gravity itself has quantum properties.

This kind of result would certainly represent a significant departure from the intuitive time-evolution picture used in the standard model. My hope is that these experiments will provide a direct window into the nature of time in our universe.



RYAN WILLS

Muons behaving oddly

Alex Keshavarzi

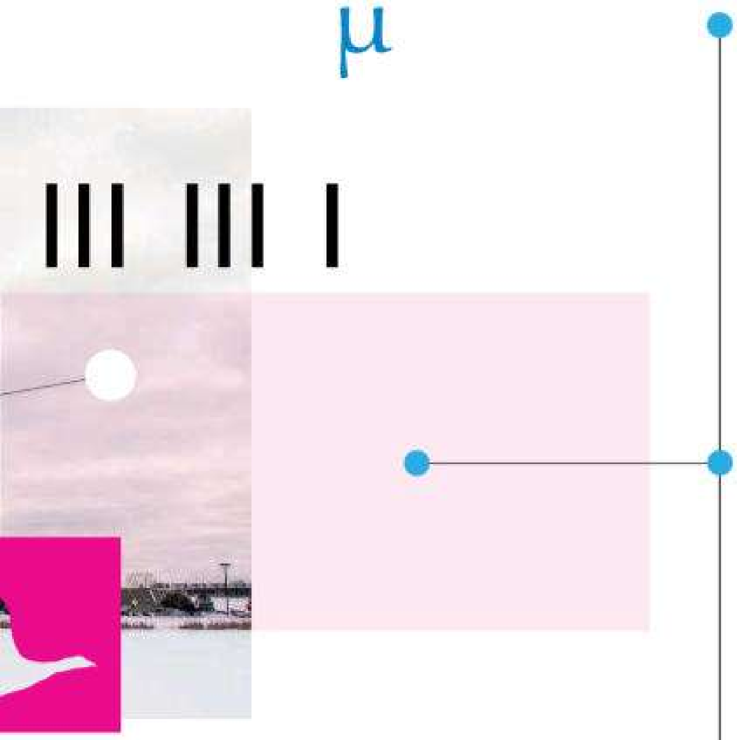
The University of Manchester, UK

FOR the past six years, a team of scientists, myself included, has been searching for new physics using an unfamiliar fundamental particle. It turns out the muon, a heavier cousin of the electron, is very useful for searching for new physics outside of the standard model.

Our experiment, based at the Fermi National Accelerator Laboratory (Fermilab), Illinois, measures a property called the muon's "magnetic moment". In a magnetic field, muons can interact with a sea of virtual particles that pop in and out of existence. Some might be particles we know of, but unknown particles could pop up, too.

These interactions cause the muons to wobble, or "precess": the more interactions the muon experiences, the faster it wobbles. Measuring this wobble can indirectly tell us how many virtual particles the muon has interacted with, and the number of forces through which it has done so. By comparing this measurement with the standard model prediction, we can see whether the muon has interacted with new particles or forces.

Back in 2004, a measurement of the



muon's magnetic moment at the Brookhaven National Laboratory, New York, found the muon's magnetic moment was larger than the standard model prediction. It had a precision of 0.5 parts per million, as precise as measuring the length of a stadium to the width of a human hair. But higher precision was needed to prove new physics.

Part of the Brookhaven experiment was moved more than 4800 kilometres to Fermilab and the Muon g-2 experiment was born. Our first result in 2021 confirmed the Brookhaven finding, and in August 2023, we released another consistent result with a precision of 0.19 parts per million: the most precise measurement ever made at a particle accelerator.

If there is new physics beyond the standard model, our measurement is precise enough to confirm it for the first time. But that rests on the standard model prediction itself, which has evolved since 2021 to have different results depending on which method is used to calculate it. Some align more with our experiment and therefore suggest there is no new physics. The rest, enticingly, are beyond the threshold needed to claim that first ever discovery of new physics.

An international collaboration of theoretical physicists known as the Muon g-2 Theory Initiative, of which I am also a member, is working very hard to understand and resolve these differences, hopefully within the next few years. Whatever the outcome, however, the Muon g-2 experiment will continue to release new results at even higher precision, with our last batch of data now ready to be analysed. I am excited to see whether our final result, expected in the next couple of years, could irrefutably confirm physics beyond the standard model for the first time.

TOP: FERMILAB; RIGHT: MEVANS/GETTY IMAGES

A new paradigm

Matt Strassler
Harvard University

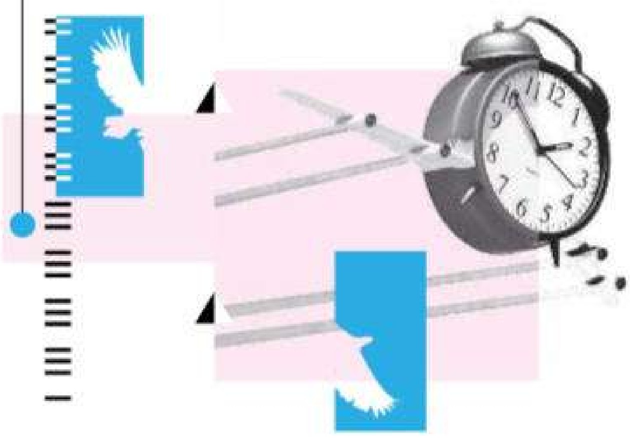
IN THE 19th century, scientists understood most waves as we understand them today: rhythmic disturbances of a medium, like sound waves through air. Once they realised light was a wave, it seemed obvious it would have a medium, too, which they called the luminiferous aether. Earth's motion through the aether was expected to cause light's speed to change slightly depending on its direction of motion, just as sound's speed does for moving observers.

In an experiment in 1887, physicists Albert Michelson and Edward Morley found no such dependence. This "null result" puzzled physicists until Albert Einstein proposed an explanation in 1905: that the speed of light never changes.

Ever since then, particle physics has been driven by a sequence of puzzles and clues that has led scientists from one discovery to the next (see "How we built the standard model", page 33). Unfortunately, this trend seems to have ended in 2012 with the discovery of the Higgs boson. I view the absence of further discoveries at the Large Hadron Collider (LHC) as potentially among the most important null results in the history of physics, comparable with the Michelson-Morley measurement.

Just as the aether result violated simple, general reasoning about waves, the LHC's null result also goes against certain basic reasoning about quantum fields. Quantum field theory seems to imply, and experiments seem to confirm, that it is highly unusual to have a Higgs field and Higgs boson that exist entirely on their own. There ought to be a whole set of additional fields and particles, of which the Higgs field and Higgs boson are just the first. Some of them should be observable at the LHC.

So far, the collider has seen nothing of the kind. While its search is far from over, many physicists like me have been wondering if the reasoning is misguided. Perhaps, as with Michelson-Morley, we might be seeing the first signs of a paradigm breaking down.



Calculations concerning the Higgs field rely on three assumptions: quantum field theory is valid; it can be used without having to account for phenomena at energies vastly larger than those probed directly by the LHC; and events in the universe's distant past don't affect the calculations. Although no one has a reasonable alternative to quantum field theory yet, it behoves us to question the other assumptions.

One option involves hidden symmetries relating traits of both known and unknown particles. These could lead to "magic zeroes", causing effects that would destabilise a lone Higgs field to be much smaller than expected. Or quantum gravity may impose unknown constraints on quantum field theories. It might be that only a few quantum field theories are consistent with gravity, and in those that resemble the standard model, the LHC's null result is automatic.

Another possibility is that the universe's history has left us with a world where this null result was necessary for our existence. The simplest version of this idea suggests our universe is a mostly uninhabitable multiverse, in which the rare habitable places are described by very unusual quantum field theories. While similar reasoning potentially explains why the cosmological constant that drives the universe's accelerating expansion is very small (see "Hunting cosmological chameleons", page 37), it fails here, merely replacing one puzzle with another.

Another idea is that the universe passed through many phase transitions, at each stage being described by a more and more unusual quantum field theory. When it reached the most unusual phase, the transitions stopped, leaving us with a surprising universe. Yet this proposal, which was made explicit through an idea known as the "relaxion", has difficulty solving the cosmological constant problem.

All of these ideas seem rather desperate, indicative of a moment when the concepts underlying particle physics may need to be rethought. If so, particle physicists face a tremendous challenge. The path forwards is unclear, making it difficult to guess which experimental efforts are worthwhile. Perhaps classic particle physics methods are no longer the answer, but what to replace or enhance them with is anyone's guess.

Physicists of the 1890s faced such obstacles, too. But they were lucky. Cathode rays and radioactivity opened up entirely new classes of experiments that could reveal the structure of atoms and the properties of particles moving at near light speed. Whether today's physicists will be so lucky remains entirely unclear. ▮

Thirsty work

Drinking is essential for life, but if you find plain water too boring, there are many alternative drinks that promise optimal hydration or other benefits. How do they measure up, asks **David Cox**

BILL DIODATO

RECENTLY, I have become somewhat obsessed with a new index on my smartwatch that purports to calculate whether I am sufficiently hydrated. The idea is to prompt the wearer to drink enough fluids to avoid dehydration. A watch tracking hydration might sound like a gimmick, but new research suggests there could be lasting health effects to being even mildly dehydrated.

One stumbling block I have faced on my hydration mission is that I find plain water, well, plain boring. But these days, there are myriad other types of fluid available, from sports and energy drinks to coconut water. Then there's my personal favourite: coffee. Aside from taste, are any of these a suitable substitute, in terms of both my health and hydration? Do I even need to think this much about my fluid intake?

Our notions about what we ought to be drinking are confounded by half-truths and questionable health claims. So, here is a guide to modern hydration, cutting through the hype to discover the science about what we really should be drinking – and how much.

Water is the main constituent of the human body, making up around half of our adult body mass. The body's balance of water intake and output is tightly regulated to keep the concentration of salts and minerals, or electrolytes, in our blood at a precise level. To prevent dehydration, hormonal and neural mechanisms are activated, stimulating thirst to encourage

“Long-term mild dehydration may cause greater biological ageing”

water intake and increased water reabsorption by the kidneys to decrease water output.

The question of whether we are drinking enough for optimal health has been a matter of contention for decades. You may have heard that we should drink eight glasses of water per day, but this figure turns out to have no scientific basis.

The first scientific recommendation for our water requirements came from a rough calculation added to a set of dietary guidelines from the US National Academy of Sciences in 1945. It was achieved through estimating that the average male diet involved consuming about 2500 kilocalories of food per day and might require 1 millilitre of water per kilocalorie for digestive purposes, equating to a daily water requirement of 2.5 litres. One problem with this figure is that it arguably overestimates how much water we need to drink, as it doesn’t take into account the fluid we ingest from our food, which makes up around 20 to 30 per cent of our intake.

Nevertheless, these estimates have stuck, helping to fuel a bottled water industry now worth around $240 billion in global sales. “In the US, it got marketed that everybody needed eight glasses of plain water. That made bottled water [sales] soar, even though water is something that you can get out of a tap for free,” says Tamara Hew-Butler at Wayne State University in Detroit, Michigan.

To fully understand how much water is needed by the body each day, last year an international consortium tracked water input and loss in more than 5500 people by giving them water to drink labelled with an isotope of hydrogen. “We found a typical man in their mid-20s, in the US or Europe, will require around 1.5 to 1.8 litres per day, and a typical woman will require around 1.3 to 1.4 litres,” says John Speakman at the University of Aberdeen, UK. “These are just averages, so if you’re active and out a lot in hot weather, you will need more than 2 litres.”

Drinking more water than you need, above thirst, usually isn’t a problem, however, as the kidneys quickly adjust to produce more urine. While it is possible to drink such an excess to cause hyponatremia, where the kidneys are unable to cope and the sodium content of the blood becomes dangerously diluted, Speakman says that, in practice, this is rare.

Instead, a more pressing problem appears to be the consequences of repeatedly not meeting our daily water needs. The long-term effects of chronic underhydration haven’t been well studied, but new data is starting to emerge. For example, a 2019 study in mice by Natalia Dmitrieva at the US National Institutes of Health and her colleagues showed that long-term suboptimal hydration caused inflammation, as well as accelerated age-related degeneration of the heart, kidneys and central nervous system. It also shortened the animals’ lives by around six months, equivalent to 15 years in humans.

Now, Dmitrieva and her colleagues ›

Ultra-processed people
Discover the dangers of ultra-processed food with Chris van Tulleken at New Scientist Live **newscientist.com/nslmag**

have investigated the impacts in humans of long-term mild dehydration, in which the body's water conservation mechanisms are activated to reduce urine output and blood sodium levels are slightly elevated but still within the normal range.

Using data gathered from 11,255 adults over a 30-year period, the researchers found that those with slightly elevated sodium levels displayed greater signs of biological ageing based on how well their heart, lungs, kidneys and immune systems were functioning.

"Detrimental effects of chronic underhydration on long-term health outcomes is a relatively new concept," says Dmitrieva. "It seems that insufficient hydration could promote accelerated ageing and therefore increase the risk of developing chronic diseases." Other research backs up this view. One 2020 study, for example, found that underhydration in people aged over 50 – as measured by elevated blood sodium levels and/or concentration of salts in urine – is associated with obesity and chronic diseases. However, it is possible that these biomarkers could be influenced by factors such as diet and the ingestion of sugary beverages.

Thirst quencher

How do you know if you are getting enough fluids? For most people, the first sign that you need a drink is thirst, although this isn't a fail-safe, as the so-called thirst reflex wanes as we get older (see "Hydration risks", below). Other signs include a dry mouth, tiredness, darker-coloured urine and feeling lightheaded.

There are two main types of dehydration. One occurs when you lose fluid and electrolytes by sweating, for example during exercise, or by vomiting or experiencing diarrhoea. The other, known as low-intake dehydration, occurs through not drinking enough. "In this case, your electrolyte levels stay the same, but there's less fluid, so the concentration of your electrolytes rises across cells," says Lee Hooper at the University of East Anglia in the UK. "It means that cells shrink a bit and changes the environment inside them."

More research is needed before we have a clear view of the link between mild dehydration and our health. "Can drinking more reduce the risk of kidney stones?" asks Hew-Butler. "Another interesting question about hydration for me is the link to cognition. Does drinking make you more alert? These are things we need to understand more about."

Throughout most of human history, people would have replenished fluids by drinking plain water, whereas today, an ever increasing array of different options is available. Earlier this year, actor Florence Pugh spoke for many when she claimed that water is "too boring to drink", preferring elderflower pressé, orange juice and tea. Scientists agree that other options are fine. "Our message is that any [non-alcoholic] fluid is good fluid and if you want to drink tea then that's adding fluid into your body," says Jennie Wilson at the University of West London. "The same is the case for coffee. There is scant evidence for it acting as a diuretic and even if it does, that would require consumption of very large amounts."

But a visit to the supermarket reveals a vast array of drink options that claim to give you a boost in other ways, not just hydration. Known in the industry as "functional beverages", two main types take up much of the room on store shelves: energy drinks and sports drinks.

Sports drinks are formulated to replace fluids and electrolytes, such as sodium, potassium and calcium, in the body during and after exercise. Originally developed for athletes, many are now marketed to the general public, though it is questionable whether these drinks offer any notable benefits over water for the average person.

Water is more than sufficient for the casual jogger or someone who goes to the gym a couple of times a week, says David Rowlands at Massey University, New Zealand. "Most of these sports drinks were designed for high performance," he says. "For most people, exercising half an hour to an hour, they might lose 1 litre of fluid at the most, which can easily be replaced with four cups of water over the couple of hours following exercise."

Many sports drinks are isotonic, which means they contain similar concentrations

Hydration risks

The people who are most likely to experience dehydration probably aren't the ones rushing out to buy the latest hydration drink to hit the shelves: older adults. One study from earlier this year showed that a quarter of over 65s have low-intake dehydration due to consuming insufficient fluid each day. This has been linked to a range of common health problems, from impaired cognition to urinary tract infections.

DOMINIKA ZARZYCKA/ALAMY

One of the reasons why older people are more vulnerable to dehydration is linked to the thirst reflex. It has long been known that the sensation of thirst steadily deteriorates as we age. On top of this, some medications can encourage fluid loss, and many older adults actively choose to drink less due to worries about accessing a toilet or incontinence, says Lee Hooper at the University of East Anglia in the UK.

"Older people also have smaller body water reserves, as body water is found in muscle which declines with age," she says. "They also concentrate urine less well, so they lose additional fluid when they go to the toilet, even when they haven't drunk enough."

To tackle this, Hooper believes that we need more public health messaging on the importance of staying hydrated with age, as well as better ways of detecting dehydration. One common recommendation has been to check the colour of your urine, as the darker the colour, the more dehydrated you are. However, given our kidneys are less able to concentrate urine as we age, this test may mistakenly suggest that you are adequately hydrated, says Hooper.

HITOSHI YAMADA/NURPHOTO/GETTY IMAGES

So many different drinks are available, but is water better?

of sugars and salts to blood. However, they are still less effective than water at hydrating the body because the sugars they contain tend to be simple sugars like fructose, glucose and sucrose, which are rapidly digested as soon as they hit the small intestine, creating a higher concentration of sugars in the gut, says Rowlands. "The problem is that the gut can only absorb so much sugar at a time," he says. "The maximum rate seems to be around 1 gram per minute. If there's more sugar than that coming in, the body holds water back, which limits the amount of fluid getting into the body."

Good hydrations

For serious amateur or professional athletes, hypotonic drinks – which still contain some carbohydrates and salts, but at a lower concentration than in blood – have been shown in some studies to be the best hydration agents. This is because of a phenomenon called solvent drag, where the steady absorption of carbohydrates and electrolytes through the gut helps draw more water into the bloodstream. Rowlands suggests that coconut water could be an alternative as it contains low concentrations of carbohydrates and electrolytes, similar to the formulation of hypotonic sports drinks.

Another drink touted for its ability to boost sports performance is beetroot juice, but this isn't to do with hydration. "This is more something that serious athletes take because it has a high nitrate content, which improves blood flow to the muscles," says Rowlands. "There's some suggestion it can improve performance in high level amateurs."

While purchasing sports drinks can be expensive, an effective rehydrating drink – providing both the fluid and nutrients that the body needs to recover from exercise – can be obtained very cheaply: cow's milk. "Milk is actually the best recovery drink of all," says Hew-Butler. "Everyone's looking for this elusive beverage that does everything, but if you can tolerate milk, it ticks all the boxes because it has protein and carbohydrates and other nutrients."

Milk and chocolate milk contain carbohydrate in the form of lactose, as well as amino acids to aid muscle synthesis, and both have been shown to assist recovery following exercise. Rowlands says that the sheer number of nutrients within milk bind to water and keep sufficient levels of fluid within the body, rather than being urinated out. But don't expect this news to dent the rise of the increasingly popular sports drink sector any time soon.

> **"Milk is actually the best sports recovery drink of all. It ticks all the boxes"**

Energy drinks are another fast growing product, worth around $46 billion globally in 2020. Particularly popular among young people, these are formulated to give an instant energy boost through stimulants such as caffeine, guarana and taurine. Many also contain a high dose of sugar. Red Bull, for example, contains 27 grams of sugar per 250 millilitre can, almost the entire 30 milligrams daily recommended maximum sugar intake for adults in the UK, as well as 80 milligrams of caffeine, which is roughly the same as that in a cup of coffee.

However, sugar-free varieties are on the rise. One of the latest is the popular drink Prime Energy, founded by social media stars Logan Paul and KSI, which contains 200 mg of caffeine per 355 ml can sold in the US or 140 mg per 330 ml can in the UK.

While energy drinks may keep you alert in the short term, they are associated with poorer sleep quality and can be problematic for anyone with heart conditions, due to the increased risk of palpitations or irregular heart rhythms – which is why these drinks carry warnings for people sensitive to caffeine and some are restricted to those over the age of 18.

Evidence also suggests that sugary energy drinks may have a dehydrating effect as they are hypertonic, meaning they contain a higher concentration of salt and sugar than in blood. "Hypertonic drinks actually draw fluid out of the body to aid in digestion," says Rowlands.

Another current trend in the beverage industry is the addition of ingredients such as ginseng, green tea, turmeric, vitamins and even protein to drinks. But Hew-Butler is sceptical about the health benefits. "A lot of it is just marketing," she says. "If you're eating a good diet, they're things that you'll be getting from your food anyway."

Where does all this leave me in my mission for better hydration? As a coffee lover, I am particularly pleased to know that it contributes to my daily hydration requirements. And while having a watch with an inbuilt monitor may seem a little excessive, it definitely acts as a useful reminder to consume extra fluids, particularly on busy days when it is easy to go many hours without drinking. As to whether it really makes any difference to my long-term health, I will have to wait and see. ▮

David Cox is a freelance writer based in Brighton, UK

The back pages

Puzzles
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60-second psychology

Not so expert

Whatever your area of interest, it would seem sensible to learn from the best. Recent research disagrees, finds **David Robson**

David Robson is an award-winning science writer and the author of *The Expectation Effect: How your mindset can transform your life*

EVERY time that I open YouTube, I am bombarded with ads offering various video masterclasses from the great and the good – often at a significant cost.

The intuitive appeal is clear. Wouldn't bestselling authors, the likes of Carol Ann Duffy or Neil Gaiman, be the best possible guides to better writing? And if you aspire to be an actor, why not spend a few hours listening to the words of an Oscar-winner like Natalie Portman?

People such as these have passed through all the ordeals necessary to reach their dreams, and they should have plenty of lessons to teach us. But we may do well to question the pearls of wisdom dropping from their lips.

Firstly, there is the risk of "survivorship bias". We tend to pin success on someone's behaviour, but people's achievements are often due to factors beyond their control – such as social and financial privilege or plain good luck. There may have been thousands of people who had exactly the same behaviours as the successful but who were unable to reach their goals. We don't hear of their failures because they never achieved fame. This gives us the sense there was something special about the high-flyers' strategies, when they really contributed very little to their achievements.

Top performers may also struggle to articulate their winning strategy to others. Many expert abilities rely on implicit knowledge that is inaccessible to the conscious mind, after all.

STEFANIKOLIC/GETY IMAGES

Once someone has gained a skill, it can be very difficult to get back inside the beginner's mind and remember the steps they went through to build that knowledge.

Such difficulties were evident in studies by David Levari at Harvard Business School and his colleagues, who recruited thousands of people to play a difficult verbal game called Word Scramble. After they had taken their turn, some players took on the role of adviser, giving tips to subsequent participants on the best tactics to use. Surprisingly, the adviser's level of skill didn't transfer to the advisee: having a true hotshot as a mentor was no better than having someone of mediocre ability.

Interestingly, the advisees did tend to rate the better performers' advice more highly – even when they had been blinded to the advisers' actual credentials. The researchers found this positive impression was linked to the detail of their descriptions. "The advice from the best performers was not better," the researchers concluded. "It just sounded better because there was more of it."

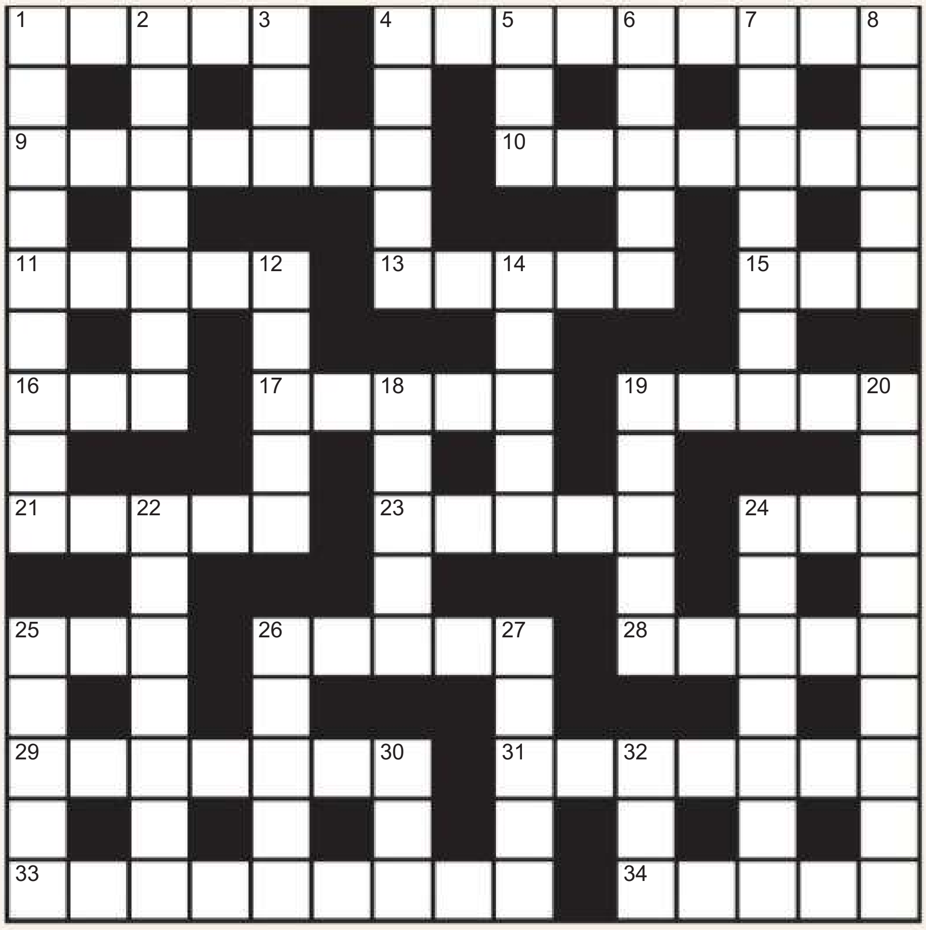
I am certainly not suggesting we should ignore our heroes, but we might take some of their guidance with a pinch of salt – particularly if they are trying to sell us a fast track to success. Some people's talents may be a mystery even to themselves, and we can admire them from afar without emulating their every move. ▮

These articles are posted each week at newscientist.com/maker

60-second psychology appears monthly

Next week
Stargazing at home

Quick crossword #141 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

1 Over; more than; extremely (5)
4 Developer of the first safe and effective polio vaccine (5,4)
9 Unregulated online spaces (4,3)
10 Gonorrhoea, informally (3,4)
11 Of or containing Os (5)
13 Warning; urgent notification (5)
15 *The* ___ *Around Us*, by Rachel Carson (3)
6 Not even (3)
7 Lawrence ___, co-winner of the 1915 Nobel prize in physics (5)
9 Bird excrement (5)
21 Metric unit of volume (5)
23 Synthetic rubber (5)
24 File extension for word-processing files (3)
25 Fundamental computing component (3)
26 Computer memory technology (2-3)
28 Nut-bearing tree in the genus *Corylus* (5)
29 Totalled; summed (5,2)
31 German measles (7)
33 ___ meridian; historical longitude 0° (9)
34 Simple triangular device (5)

DOWN

1 Device to reduce drag on the hull of a boat (9)
2 Conic solid with a polygonal base (7)
3 Spreadsheet component (3)
4 ___ the Hutt, *Star Wars* villain (5)
5 Louse egg (3)
6 Perspiration (5)
7 Absence of an organ or other tissue (7)
8 κ (5)
12 Hawser; wire (5)
14 2^3 (5)
18 Fossilised tree resin (5)
19 Cockatoo species (5)
20 Move back and forth, perhaps (9)
22 ___ wheel, device for measuring distance (7)
24 Temporarily blinded by brightness (7)
25 Metallic noise (5)
26 Unit of genetic code (5)
27 Variation of form within a species (5)
30 Φ (3)
32 Bend (3)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #218
set by Bethan Ackerley

1 What was the first vessel known to have traversed the Northwest Passage?

2 Dapsone, rifampicin and clofazimine are used to treat which condition?

3 What were Weber bars designed to detect?

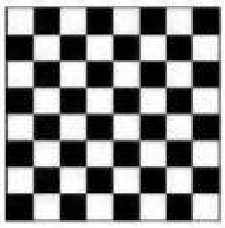
4 The unusually cold summer in the northern hemisphere in 1816 is thought to have been predominantly caused by the eruption of which volcano?

5 The white outer layer of the human eyeball is known as what?

Answers on page 47

Headscratcher
set by Sam Hartburn
#238 Knight shift

"I've heard that whatever square I start from, and no matter what path I take, I can always make at least 10 moves without landing on a square I've already been on," said the white knight.



The black knight tested it out. After jumping onto a particular black square somewhere in the top left-hand quarter of the chess board, she made three hops, but there were now no squares she could move to that she hadn't already visited. "That wasn't 10!" she said.

"Maybe you were unlucky," said the white knight. The black knight set off from where she had finished before. Her first three hops retraced her earlier moves, then she made another six hops, visiting at least one square in every column and making exactly one hop into the lower half of the board. After these nine moves, she was stuck once more. "Still one short. So much for your theory!" she said.

Can you retrace her path? Knights can move three squares in an L shape in any direction.

Solution next week

Holding hands

If every human lined up facing north with their arms outstretched and touching, at what latitude would this closed circle be?

Mike Follows
Sutton Coldfield, West Midlands, UK

If the world's population stood on the equator with outstretched arms and fingers touching, there would be enough people to circle Earth more than 300 times.

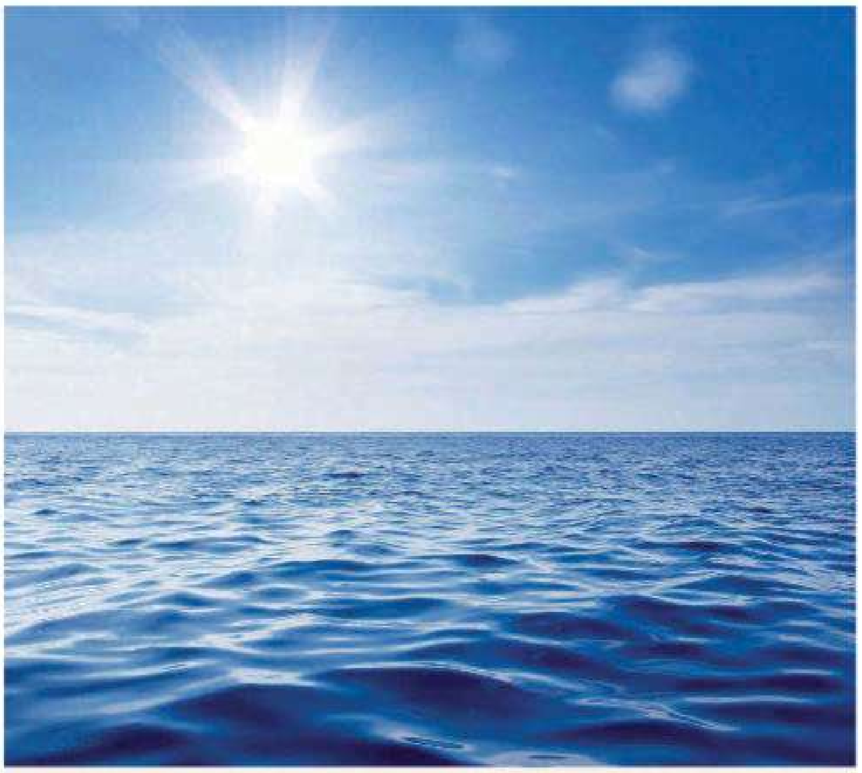
The arm span of a person is close to their height, and the average height of an adult *Homo sapiens* is 168.5 centimetres.

The average radius of Earth is 6371 kilometres, but because the planet is slightly oblate (fatter around its middle), the equatorial circumference is 40,075 km. According to worldometers.info, the world population was an unfeasibly precise 8,053,332,437 on 11 August 2023. If there were no children, only adults, this population could wrap itself around the equator almost 340 times. By integrating a graph of height against age, our estimate of the average height of a human falls to 155.9 cm and the number of loops of the equator drops to 313.

> "This all assumes that everyone is standing at sea level on a smooth surface, with the oceans removed so we could breathe"

This all assumes that everyone is standing at sea level on a smooth surface, with the oceans removed so that they could all breathe. Taking account of topography – the ups and downs of Earth's surface – would reduce the number of loops by a little.

There is an urban myth that Earth would be smoother than a billiard ball if it were shrunk down to the same size. The truth is that it would be rounder than a billiard ball, despite being oblate, but it wouldn't be as smooth. On the scale of a billiard ball, Everest and the Mariana trench would depart from sea level by between 40 and 50 micrometres respectively. Given that a human finger can feel wrinkles as small as 10 nanometres, a billiard-ball sized Earth would feel like very fine micro-grit sandpaper.


SONGCHAI W/SHUTTERSTOCK

Could bringing the cold depths of the ocean up to the surface solve the warming problem?

This week's new questions

Mixing it up **The surface of the oceans is warming, but there must be lots of cold water in the depths. Couldn't we just stick a giant egg whisk down there and stir things up a bit to solve the warming problem?** ***Paul Stapleton***, *Santa Fe, New Mexico, US*

Time for bed **Are we conscious when we are asleep?** ***Mike Holden***, *Settle, North Yorkshire, UK*

Colin Davies
Sheffield, South Yorkshire, UK

The circumference of Earth at its equator is 40,075 kilometres. For 8.05 billion people to fit along this circumference, each would somehow have to squeeze into a gap of just under 5 millimetres. Perhaps it would help if we all breathed in.

The distance from fingertip to fingertip with arms stretched out sideways is clearly going to vary with age and stature. For an upper-bound estimate we could use the traditional measure known as a fathom, which was originally defined in just such a way for an adult male and is nowadays standardised as 6 feet, or around 1.83 metres. Multiplying this distance by the global population figure gives a total of 14.7 million kilometres, which, if we all stood in a ring, would form a circle with a radius of 2.34 million kilometres. That is a little over six times the radius of the moon's orbit around Earth. If you waved to a friend standing opposite you in this ring, it would take almost 16 seconds before they could see the gesture – that is how slowly light travels.

Robert Fizek, who asked the question, writes from Newton, Massachusetts, which apparently lies at a latitude of 42.34° north. Earth's circumference at this latitude would, by simple trigonometry, be some 29,600 kilometres.

Allowing 1.83 metres of arm-swinging space per person, you could stand some 16.2 million people at that latitude in a north-facing ring (which, according to the most recent reliable-looking estimate I could quickly find, would be around 2.3 times the population of Massachusetts).

Simon Rundle
Shepton Mallet, Somerset, UK

While the general solution for an arbitrary band around an arbitrary sphere involves some maths, the specific solution is simpler. A population of 8 billion spaced at 1-metre intervals will circumnavigate the equator (40,000 km) 200 times. As 75 per cent of this path is underwater, if the population can be persuaded to do this, it may also provide a solution for the planet's current environmental difficulties.

Brad Kuhns
Via Twitter

It would vary over time. Everyone over an ocean would drown, which would decrease the population, and everybody standing on land would have to march north until they got to pure ice. Then the population would be stable.

Simon Strong
Hertford, UK

A back-of-the-envelope calculation shows that if you divide the length of the equator by the world population, then each person only has 5 millimetres of room to stand in, so this isn't going to work. However, if the population of the UK (67 million) stood around the equator, each person would have about 60 cm, so standing shoulder to shoulder would be possible. Or you could fit the world population around the circumference of

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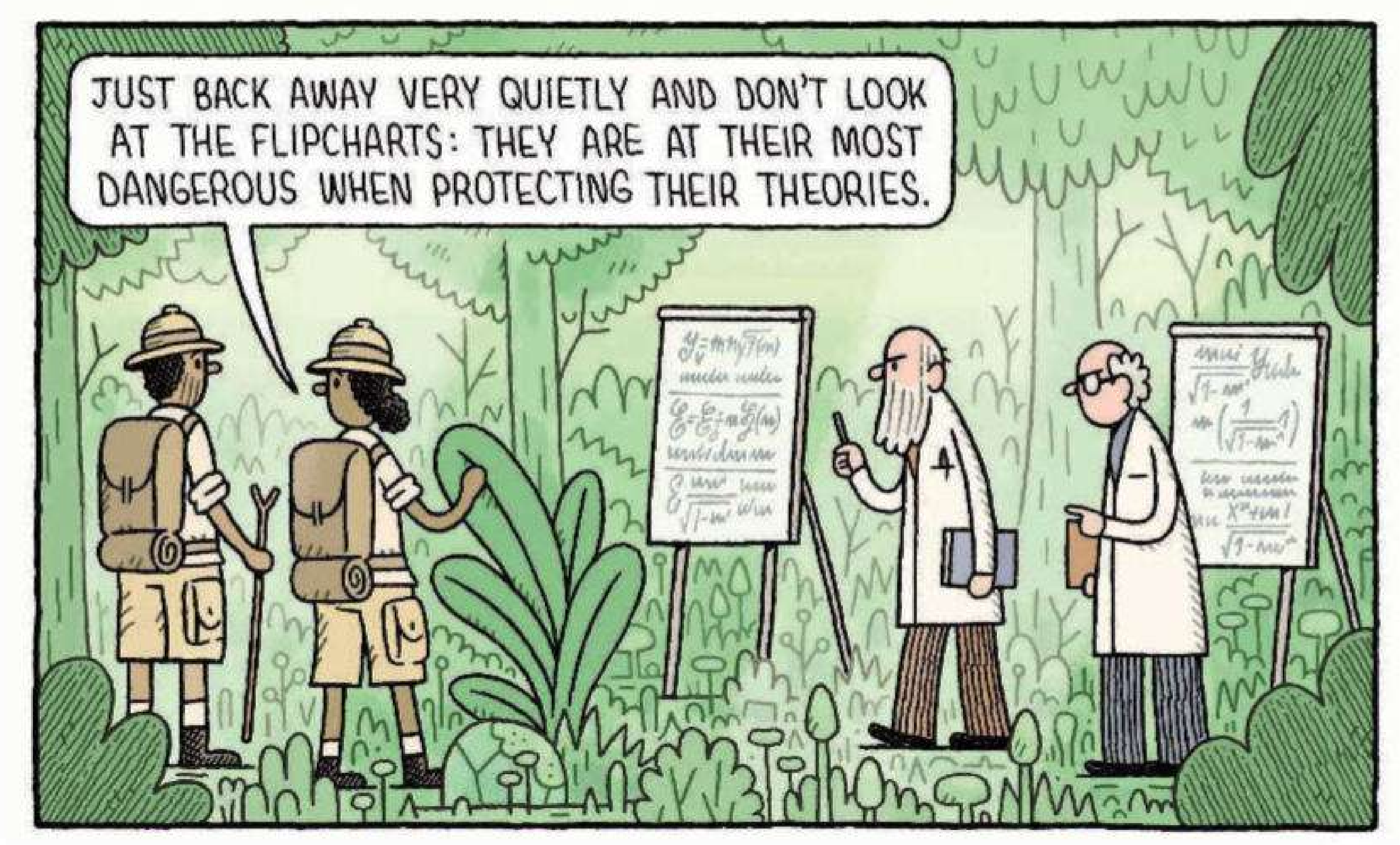

JUST BACK AWAY VERY QUIETLY AND DON'T LOOK AT THE FLIPCHARTS: THEY ARE AT THEIR MOST DANGEROUS WHEN PROTECTING THEIR THEORIES.

the sun (4.4 million km) and give each person about 55 cm.

For the love of rats

Given the huge ecological impact that domestic cats can have on their surroundings, why don't we domesticate more rats as our family pets, rather than vilifying them?

Barbara Sommerville
Wallingford, Oxfordshire, UK
I have worked a lot with laboratory rats, and they could make excellent pets, but they would need serious genetic modifications to be made to them. Particularly, they would need their lifespan to be extended considerably because they only live for about two years.

My lab rats were exceedingly intelligent, hard working and affectionate with gentle people. If one started with wild rats, they may need to be made rather more placid, but this might be rectified by training and environment. I suspect these wild rats would be hyper-intelligent.

> "My lab rats were exceedingly intelligent, hard working and affectionate with gentle people"

Nicole Keshav
Cambridge, UK
I believe people do raise many domesticated rats for lab use, and a few of these domesticated rats become pets. While I think they can be lovely pets, they are widely perceived to be similar to wild rats, which makes them less popular than other domesticated animals with less resemblance to their wild relatives. We are unlikely to mistake a domesticated cat for a wild cat, for example, or a dog for a wolf. Domesticated rats seem very like the wild ones to untrained eyes. Of course, a loving pet owner might disagree!

All in the mind

Why can't we conjure up smell and touch in our heads, but we can "listen" to music when nothing is coming through our ears? (cont.)

James Northover
Poole, Dorset, UK
This surely must vary from person to person in the same way some individuals are unable to visualise images in their head, often referred to as aphantasia. The vividness of these virtual senses may be correlated with each other, as a 2020 study suggests that people with aphantasia often report decreased mental "imagery" in the other senses.

Speaking for myself, I have no difficulty in conjuring up sensations of touch and odours in my head, including of things that don't exist in our reality. This comes in handy as a writer of fiction.

Pauline Fothergill
Pocklington, East Yorkshire, UK
But I do! Flavours too. I never thought anything of it. I thought everyone was able to. So, now I need to know – is this my latest trivial superpower? ▮

Answers

Quick quiz #218
Answers

1 The Gjøa
2 Leprosy, or Hansen's disease
3 Gravitational waves
4 Mount Tambora, in what is now Indonesia
5 The sclera

Cryptic crossword #117 *Answers*

ACROSS 1 Sea otter, **5** Ibid, **8** Air, **9** Salt licks, **11** Grade, **12** Settle, **14** Revolt, **16** Punish, **18** Grotto, **19** Pique, **22** Deep sleep, **23** Bud, **24** Year, **25** Doorstop

DOWN 1 Swaggers, **2** Aorta, **3** Tessellates, **4** Enlist, **6** Bacilli, **7** Dust, **10** Litmus paper, **13** Sheep dip, **15** Verbena, **17** Pomelo, **20** Qubit, **21** Edgy

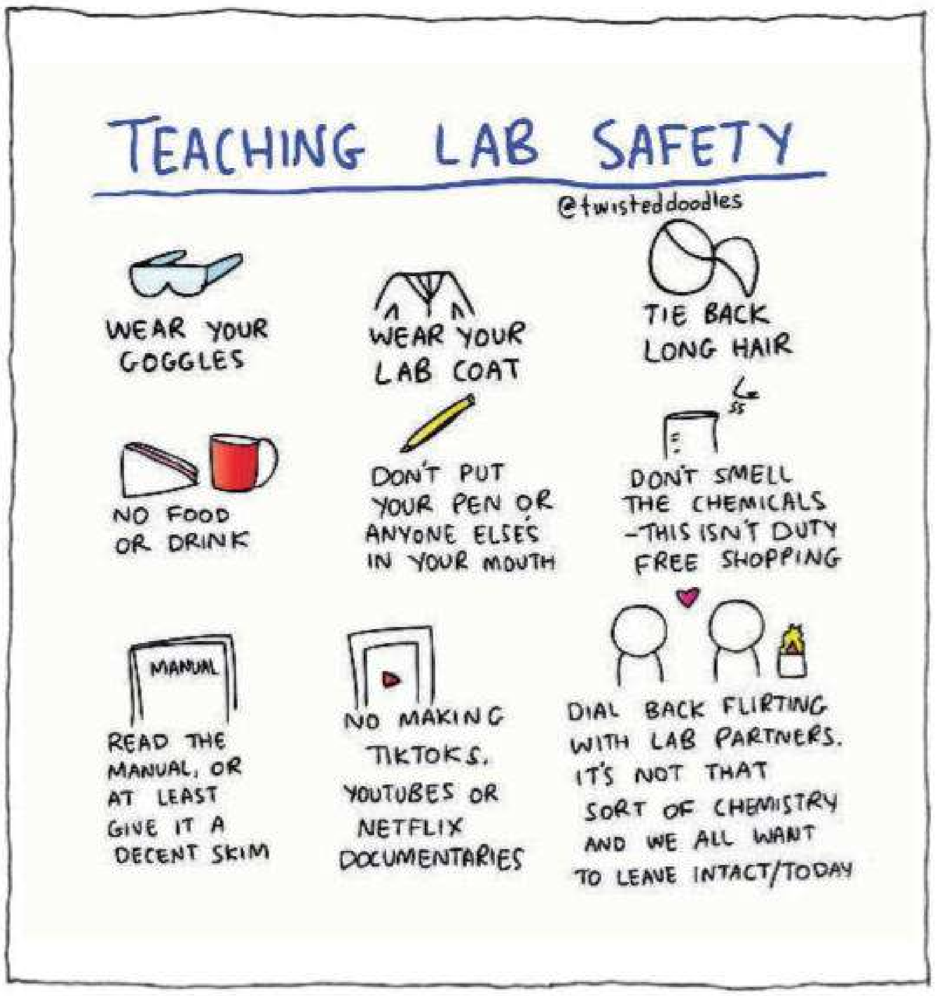
#237 Golden oldie
Solution

The padlock code was 1089, regardless of which year Rumpelschtumpel was born.

The difference between a three-digit number (ABC) and its reverse (CBA) is 99(A - C), i.e. it is a multiple of 99. The multiples (XYZ) are 198, 297, 396 and so on, and each of these when added to its reverse is 1089 (e.g. 198 + 891 = 1089).

Note that if A and C are the same digit, then XYZ is 000. So, if 1089 doesn't work, Prince Hopeful should try 0000 on the padlock.

Twisteddoodles *for New Scientist*


TEACHING LAB SAFETY
@twisteddoodles
WEAR YOUR GOGGLES
WEAR YOUR LAB COAT
TIE BACK LONG HAIR
NO FOOD OR DRINK
DON'T PUT YOUR PEN OR ANYONE ELSE'S IN YOUR MOUTH
DON'T SMELL THE CHEMICALS – THIS ISN'T DUTY FREE SHOPPING
MANUAL
READ THE MANUAL, OR AT LEAST GIVE IT A DECENT SKIM
NO MAKING TIKTOKS, YOUTUBES OR NETFLIX DOCUMENTARIES
DIAL BACK FLIRTING WITH LAB PARTNERS. IT'S NOT THAT SORT OF CHEMISTRY AND WE ALL WANT TO LEAVE INTACT/TODAY

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Consideration of items sent in the post will be delayed

Time for a nap

Brainy people get to dream a little more than not-quite-so-brainy people, correlationally speaking, if their brains and genomes accord with the findings of researchers from the University of the Republic in Uruguay, University College London and the Broad Institute in Massachusetts.

"Our findings suggest a modest causal association between habitual daytime napping and larger total brain volume," the researchers say in a study published in the journal *Sleep Health*.

They crunched numbers obtained from brain scans and genetic information. The crunching involved brain sizes (normalised, says the report, for people's head sizes) from one group of people. The crunching also made use of other, genetically-similar-in-some-ways people's answers to the question "do you have a nap during the day?".

The team notes that "napping is notoriously difficult to measure using objective methods". Fighting to overcome that difficulty, the numerical crunching joined together genome info from the scanned group and the nap-queried group. Previous research had produced the knowledge – or suspicion – that certain stretches of DNA seem to be associated with a person's proclivity to nap.

Feedback is eager to see the modesty of the causal association evident in future head-size-normalised, genome-augmented studies, if there are any, of habitual daytime napping in huge and tiny animals (elephants, perhaps, and fruit flies), in notoriously nap-loving dogs and cats, and in two and three-toed sloths. Thanks to Kit Thompson for awakening us to this line of research.

Beyond sloth sleep

Scientists have been awake to many facets of sloths, but not so much to their hair.

Perhaps the most beloved sloth study was done 15 years ago and given the title "Sleeping outside the box: Electroencephalographic measures of sleep in sloths inhabiting a rainforest". It looked at electroencephalogram recordings of snoozing "brown-throated three-toed sloths (*Bradypus variegatus*) inhabiting the canopy of a tropical rainforest". That experience led the researchers, a team from Germany, Switzerland, the US and Panama, to "suggest that sleep in the wild may be markedly different from that in captivity".

Now, awakened to the range of sloth unknowns, an Australian team has published a study called "Sloths: The unusual hairs from these shaggy heteroclites". The researchers hasten to explain their interest: "extensive studies have been conducted on sloth phylogeny, anatomy and locomotion, suspensory lifestyle, mutualism and even their sleeping habits. However, in comparison, there are fewer articles that concentrate on another unusual feature of these ancient creatures – their hair."

After studying hairs from two-toed and three-toed species of sloth, the researchers report that, in most respects, "their hairs did not differ greatly from each other or from that found in other mammals".

Apples and onions

Elizabeth Gilliard cries foul over a medical team's inconclusive conclusion, as reported by Feedback on 12 August, that "the effects of apples and apple derivatives on disease risk reduction are both challenging and encouraging".

"The present day maxim is a corruption," Elizabeth tells Feedback, because "the original was 'an onion a day keeps the doctor away', and a roast onion is still reckoned good for colds."

Researchers in the US looked at the apple/onion distinction, then presented their findings at the American Thoracic Society's 2023 International Conference in Washington DC. They called their report "An apple or onion a day keeps the doctor away: Association of dietary quercetin with less acute respiratory illness and chronic cough".

The researchers got their data from a "food frequency questionnaire" carried out in 2003-2004 that asked people about their "consumption of apples and onions in the previous 12 months". The data convinced them, they report, of at least three things. First, that eating at least an onion a day resulted in slightly greater odds of "not having a head or chest cold" if you were one of the people who answered that survey. Second, that there was no such association with eating apples.

Third, that quercetin, "a flavonoid abundant in onions and apples" and "a key component of the Mediterranean diet", may be "a biologically plausible therapeutic to prevent/treat acute respiratory illness". But, they add, maybe traditionally, more research is needed.

Eclipse of a meeting

Two persistent activities that physicists pride themselves on: achieving higher accuracy and seeking awareness of confounding factors. The American Physical Society (APS) displayed both qualities in this recent announcement: "The 2024 APS April Meeting dates have been adjusted to Wednesday, April 3, through Saturday, April 6, 2024 – three days earlier than initially planned."

"The decision to shift the dates," it goes on to say, "was driven by member feedback regarding the total solar eclipse that will take place on April 8, 2024." ▮

Marc Abrahams

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